COSEWIC
Assessment and Status Report

on the

Cassin's Auklet
Ptychoramphus aleuticus

in Canada

SPECIAL CONCERN
2014

COSEWIC
Committee on the Status
of Endangered Wildlife
in Canada

COSEPAC
Comité sur la situation
des espèces en péril
au Canada

COSEWIC status reports are working documents used in assigning the status of wildlife species suspected of being at risk. This report may be cited as follows:

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COSEWIC
Assessment Summary

Assessment Summary – November 2014

Common name
Cassin's Auklet

Scientific name
Ptychoramphus aleuticus

Status
Special Concern

Reason for designation
About 75% of the world population of this ground-nesting seabird occurs in British Columbia. Overall, the Canadian population is thought to be declining, but population monitoring has been insufficient to determine size and trends. The species faces threats from mammalian predators that have been introduced to its breeding islands. While predators have been removed from some breeding colonies, it is likely that ongoing predator management is going to be needed to maintain the species. The species also faces other threats when it forages at sea, including large-scale climate change effects on its oceanic prey, and risks from oiling.

Occurrence
British Columbia, Pacific Ocean

Status history
Designated Special Concern in November 2014.

COSEWIC
Executive Summary

Cassin's Auklet
Ptychoramphus aleuticus

Wildlife Species Description and Significance

Cassin's Auklet is a small grey seabird in the Family Alcidae. About 75-80% of the global population breeds in British Columbia. This species comprises almost half of all seabirds nesting in British Columbia.

Two subspecies are recognized, *Ptychoramphus aleuticus aleuticus* and *P. a. australis.* Only the former subspecies is found in Canada.

Distribution

Cassin's Auklets are found along the Pacific coast of North America. They spend most of their lives at sea and come to land only to breed. Most nest in colonies on coastal islands from the western Aleutian Islands in Alaska to central Baja California; they occasionally nest in Siberia and on the Kuril(e) Islands in Japan/Russia. During the non-breeding season, the birds are found mainly from southeast Alaska through Baja California, with concentrations off California.

Habitat

Cassin's Auklets nest on islands that are free of native mammalian predators, such as raccoons and mink. In British Columbia, the vast majority nest in burrows in forested or treeless habitats. Most burrows are within 100 m of the shoreline. The amount of suitable nesting habitat has declined over the past 75 years due to introductions of mammalian predators to colony islands. Changes to vegetation have also decreased the amount of high-quality nesting habitat on some islands since the 1980s.

At sea, the Cassin's Auklet inhabits two oceanographic domains: the California Current System, which extends from the northern tip of Vancouver Island through Mexico, and the Alaska Current System farther north. The birds' marine habitat is highly variable over multiple temporal scales. Atmospheric/oceanographic processes that elevate ocean temperatures (e.g., warm water phases of the Pacific Decadal Oscillation) are associated with reduced Cassin's Auklet reproductive performance while those that cause extreme climate events (e.g., El Niño events) can lower adult survival rates.

Biology

Cassin’s Auklets lay a single-egg clutch, which is incubated by both parents on alternating days for about 38 days. After the egg hatches, parents return to the burrow at night to feed the nestling for about 45 days. The young are independent at fledging.

In the California Current System, Cassin’s Auklet reproductive success and fecundity are reduced during warm water years due to declines in food availability. Reduced reproductive success is attributed to a temporal mismatch between the nestling provisioning period and the birds’ critical zooplankton prey, which peaks in abundance earlier and for a shorter duration during warm water years. In addition, adult survival is reduced during extreme climate events. In contrast, Cassin’s Auklets in the Alaska Current System show reduced survival during El Niño events, but no effects on reproductive performance.

Population Sizes and Trends

The global population of Cassin’s Auklet is estimated at 3.57 million breeding individuals, of which about 2.69 million (75%) nest in Canada. Triangle Island is the world’s largest Cassin’s Auklet colony and alone supports about 55% of the global population. Over the last 75 years, colonies have been extirpated by introduced predators: rats, raccoons and mink. The magnitude of decline is largely unknown because population data are available for fewer than 30 years.

Threats and Limiting Factors

The main threats are climate change, introduced predators and oil spills. Climate change is expected to result in warmer ocean temperatures and more frequent El Niños, both of which have negative consequences for Cassin’s Auklet reproduction and survival. The impacts are expected to be most severe and immediate in the California Current System. Rats, raccoons and mink cause notable destruction to, and possibly extirpations of, colonies. The threat of oil contamination from chronic or catastrophic spills is ongoing and expected to increase if offshore vessel traffic increases.

Protection, Status, and Ranks

Cassin’s Auklet is categorized as a species of “Least Concern” according to the IUCN Red List and its global status is “Apparently Secure”. Nationally and provincially, the breeding population is considered vulnerable to imperilled, whereas the non-breeding population is considered apparently secure. Cassin’s Auklet has been placed on the British Columbia Blue List as a species of Special Concern. It is an Identified Species under the province’s Identified Wildlife Management Strategy in the *Forest Range and Practices Act.* Only one breeding colony (supporting less than 1% of the population) does not have formal protection in British Columbia.

TECHNICAL SUMMARY

Ptychoramphus aleuticus

Cassin's Auklet — Starique de Cassin

Range of occurrence in Canada: British Columbia, Pacific Ocean

Demographic Information

Generation time (usually average age of parents in the population) Range 6-8 years with 7 years as an average; based on IUCN (2011) guidelines.	7 yrs
Is there an [inferred] continuing decline in number of mature individuals? Decline in number of mature individuals is inferred from decline in number of burrows in permanent monitoring plots on the largest colony (occupancy rates were not measured); plots included about 0.2% of total burrows in the colony when established in 1989. Decline is extrapolated only to colonies in the California Current System. Declines are also supported by Aboriginal traditional knowledge.	Yes, for birds nesting along the north and west coasts of Vancouver Island.
Estimated percent of continuing decline in total number of mature individuals within [2 generations] Rate of decline is expected to vary with natural cycles in marine environment; periodicity of those cycles is not precise.	Unknown
[Inferred] percent [reduction] in total number of mature individuals over the last [3 generations]. Overall, it is presently difficult to assign a rate of decline, especially since it is unknown the extent to which the population may be oscillating, as opposed to showing a linear trajectory. A rate of decline of ~30% for the Canadian population could be inferred from the 40% decline in number of burrows at one large colony (occupancy rate is unknown) that is located in the California Current System. The 40% decline is extrapolated only to colonies in the California Current System, which represents about 75% of the Canadian population. The remainder of the Canadian population is assumed stable.	Unknown rate of decline
[Suspected] percent [reduction] in total number of mature individuals over the next [3 generations]. Declines are likely, given continued ocean warming and other threats. Rate of decline will likely be lower in the near future as the Pacific Decadal Oscillation shifts to the cold water phase. Future losses due to introduced predators are unquantifiable and the timing of those losses to within 3 generations is unknown.	Unknown
[Inferred] percent [reduction] in total number of mature individuals over any [3 generations] period, over a time period including both the past and the future.	Unknown

Are the causes of the decline clearly reversible and understood and ceased? The relative contributions of climate change and natural cyclic variation in ocean conditions to the observed decline (1989-2009) are undetermined. Anthropogenic ocean warming is not reversible in the short term. Introduced predators can be eradicated from colony islands, but will remain a threat without ongoing management.	No
Are there extreme fluctuations in number of mature individuals? Although the total number of breeding mature individuals changes rapidly (in response to extreme weather events) and frequently (approximately once per generation), the variation is not typically of more than one order of magnitude.	No

Extent and Occupancy Information

Estimated extent of occurrence Calculated as a minimum convex polygon, based on the location of extant colonies.	67,100 km^2
Index of area of occupancy (IAO) Calculated as number of 2x2 km grid cells; based on the location of colonies with one additional grid cell included for Triangle Island.	228 km^2
Is the population severely fragmented?	No
Number of locations Based on the occurrence of 62 extant colonies. Colonies are considered separate locations because some threats to which the birds are exposed, including the serious threat of introduced predators, are colony-specific.	>10
Is there a [projected] continuing decline in extent of occurrence?	No
Is there a [projected] continuing decline in index of area of occupancy? Declines in nesting areas are expected due to reduced populations and climate-driven vegetation changes. Colony extirpations or significant declines are expected to follow introductions of non-native predators, barring successful ongoing predator control.	Yes
Is there an [observed, inferred, or projected] continuing decline in number of populations? The entire Canadian population is considered a single population.	Not applicable
Is there an [observed, inferred, or projected] continuing decline in number of locations? Extirpations due to introduced predators are possible, but the probability cannot be determined.	Possible

Is there a [projected] continuing decline in [area and quality] of habitat? Marine habitat quality in the California Current System is expected to continue to decline in quality with ocean warming; availability of high-quality nesting habitat is expected to continue to decline as vegetation changes; loss of habitat due to introduced predators is expected.	Yes
Are there extreme fluctuations in number of populations?	Not applicable
Are there extreme fluctuations in number of locations?	No
Are there extreme fluctuations in extent of occurrence?	No
Are there extreme fluctuations in index of area of occupancy?	No

Number of Mature Individuals (in each population)

Population	**N Mature Individuals**
Total Number of Breeding Individuals (an unknown number of mature non-breeding individuals may be present but uncounted in the population). Based on surveys conducted between 1977 and 2011. Population estimates derived from surveys conducted prior to the 1980s are highly uncertain. Nevertheless, the Canadian population is likely somewhere between 1-3 million individuals.	2,689,000

Quantitative Analysis

Probability of extinction in the wild is at least [20% within 20 years or 5 generations, or 10% within 100 years].	Not available

Threats (actual or imminent, to populations or habitats)

Known Threats: • Ocean warming/climate change • Introduced predators • Extreme climate events • Climate-driven vegetation change • Chronic and catastrophic oil spills • Shipping • Human disturbance Possible Future Threats: • Offshore oil and gas development • Offshore wind turbines	

Rescue Effect (immigration from outside Canada)

Status of outside population(s)? Only about 25% of the population occurs outside Canada. In California, the largest colony has declined by 85% since 1971; the annual rate of decline was 2.4% after 1991. The Alaskan population may have increased over the last several decades following the eradication of introduced predators from many islands.	California population declining; status of Oregon and Washington populations unknown; no trend data for Alaska
Is immigration known or possible?	Yes

Would immigrants be adapted to survive in Canada?	Yes
Is there sufficient habitat for immigrants in Canada? Declining ocean habitat quality in the California Current System is a serious threat.	Yes in the Alaska Current System; no in the California Current System
Is rescue from outside populations likely? The marine conditions causing the population decline will persist in the absence of a reversal of ocean warming. Thus, rescue of the California Current System portion of the population is unlikely. Populations to the south are almost certainly declining and rescue from that region is unlikely. Recovery has been documented on islands from which introduced predators were eradicated, but has been very slow in British Columbia. Strong site fidelity and low natal dispersal suggest that rescue from Alaska would be slow.	Possibly from Alaska

Data-Sensitive Species

Is this a data-sensitive species?	No

Status History

COSEWIC: Designated Special Concern in November 2014.

Status and Reasons for Designation:

Status: Special Concern	**Alpha-numeric code**: Not applicable
Reasons for designation: About 75% of the world population of this ground-nesting seabird occurs in British Columbia. Overall, the Canadian population is thought to be declining, but population monitoring has been insufficient to determine size and trends. The species faces threats from mammalian predators that have been introduced to its breeding islands. While predators have been removed from some breeding colonies, it is likely that ongoing predator management is going to be needed to maintain the species. The species also faces other threats when it forages at sea, including large-scale climate change effects on its oceanic prey, and risks from oiling.	

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): Not applicable. Rates of decline cannot be calculated at this time and probably do not exceed thresholds.
Criterion B (Small Distribution Range and Decline or Fluctuation): Not applicable. Range exceeds thresholds.
Criterion C (Small and Declining Number of Mature Individuals): Not applicable. Population size exceeds thresholds.
Criterion D (Very Small or Restricted Population): Not applicable. Both population and distribution exceed thresholds.
Criterion E (Quantitative Analysis): Not done.

COSEWIC HISTORY

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) was created in 1977 as a result of a recommendation at the Federal-Provincial Wildlife Conference held in 1976. It arose from the need for a single, official, scientifically sound, national listing of wildlife species at risk. In 1978, COSEWIC designated its first species and produced its first list of Canadian species at risk. Species designated at meetings of the full committee are added to the list. On June 5, 2003, the *Species at Risk Act* (SARA) was proclaimed. SARA establishes COSEWIC as an advisory body ensuring that species will continue to be assessed under a rigorous and independent scientific process.

COSEWIC MANDATE

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) assesses the national status of wild species, subspecies, varieties, or other designatable units that are considered to be at risk in Canada. Designations are made on native species for the following taxonomic groups: mammals, birds, reptiles, amphibians, fishes, arthropods, molluscs, vascular plants, mosses, and lichens.

COSEWIC MEMBERSHIP

COSEWIC comprises members from each provincial and territorial government wildlife agency, four federal entities (Canadian Wildlife Service, Parks Canada Agency, Department of Fisheries and Oceans, and the Federal Biodiversity Information Partnership, chaired by the Canadian Museum of Nature), three non-government science members and the co-chairs of the species specialist subcommittees and the Aboriginal Traditional Knowledge subcommittee. The Committee meets to consider status reports on candidate species.

DEFINITIONS
(2014)

Wildlife Species	A species, subspecies, variety, or geographically or genetically distinct population of animal, plant or other organism, other than a bacterium or virus, that is wild by nature and is either native to Canada or has extended its range into Canada without human intervention and has been present in Canada for at least 50 years.
Extinct (X)	A wildlife species that no longer exists.
Extirpated (XT)	A wildlife species no longer existing in the wild in Canada, but occurring elsewhere.
Endangered (E)	A wildlife species facing imminent extirpation or extinction.
Threatened (T)	A wildlife species likely to become endangered if limiting factors are not reversed.
Special Concern (SC)*	A wildlife species that may become a threatened or an endangered species because of a combination of biological characteristics and identified threats.
Not at Risk (NAR)**	A wildlife species that has been evaluated and found to be not at risk of extinction given the current circumstances.
Data Deficient (DD)***	A category that applies when the available information is insufficient (a) to resolve a species' eligibility for assessment or (b) to permit an assessment of the species' risk of extinction.

* Formerly described as "Vulnerable" from 1990 to 1999, or "Rare" prior to 1990.

** Formerly described as "Not In Any Category", or "No Designation Required."

*** Formerly described as "Indeterminate" from 1994 to 1999 or "ISIBD" (insufficient scientific information on which to base a designation) prior to 1994. Definition of the (DD) category revised in 2006.

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The Canadian Wildlife Service, Environment Canada, provides full administrative and financial support to the COSEWIC Secretariat.

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WILDLIFE SPECIES DESCRIPTION AND SIGNIFICANCE

Name and Classification

Cassin's Auklet, *Ptychoramphus aleuticus,* belongs to the Class Aves, Order Charadriiformes and Family Alcidae (AOU 1957). The French name is Starique de Cassin. Aboriginal names include *hajaa* in southern Haida, *hadjá* in northern Haida, *Maamaati* (bird) in Nuh-chah-nulth and *spyu* in Nuxalk. Two subspecies are recognized, *P. a. aleuticus* and *P. a. australis.* Only the former subspecies is found in Canada.

Morphological Description

Cassin's Auklets are small (150-200 g), compact seabirds with short wings. Their plumage is dark grey above, gradually fading to light grey below and white on the belly; there are small white crescents above and below the eyes. Breeding and basic (winter) plumages are similar and sexual dimorphism is subtle: adult males have deeper bills than adult females (Nelson 1981). Iris colour is related to age. Nestlings have brown irides and eye colour progresses to white over several years; most breeding adults have white irides (Manuwal 1978).

The two subspecies are morphologically similar, but the southern subspecies is smaller. Adult body mass increases from Baja California to northern California; birds from British Columbia and Alaska are similar in size to those in northern California (Ainley *et al.* 2011).

Population Spatial Structure and Variability

Two subspecies of *P. aleuticus* are recognized: *P. a. aleuticus* breeds from the Aleutian Islands in Alaska to Guadalupe Island in Baja California, while the more southerly *P. a. australis* breeds from San Benito Island to Asunción and San Roque islands in Baja California (Figure 1; Ainley *et al*. 2011).

Wallace *et al.* (in press) recently provided the first characterization of the population genetic structure of Cassin's Auklet and found that the two subspecies were genetically differentiated. However, birds breeding at the Channel Islands in southern California, which are presently classified as *P. a. aleuticus*, are genetically more similar to *P. a. australis*. Further genetic differentiation within either the northern or southern group of birds was not found. Wallace *et al.* (in press) suggested that the two genetic groups should be considered separate management units.

Wallace *et al.* (in press) estimated significant gene flow from the northern group of birds to the southern group. They suggested that the two groups did not represent separate evolutionary significant units.

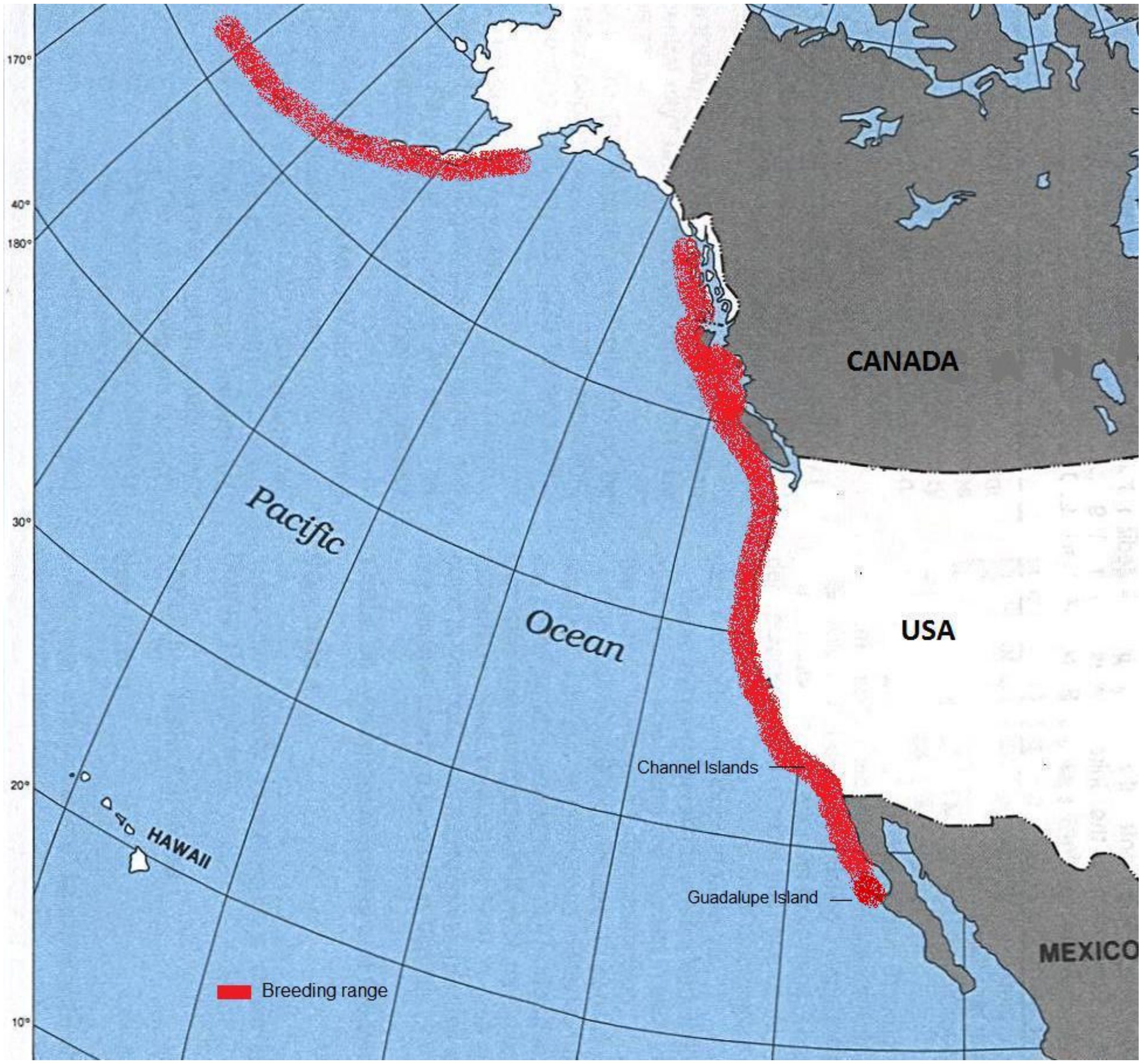

Figure 1. Breeding range of Cassin's Auklet.

Designatable Units

The genetic structure of the species described by Wallace *et al.* (in press; see preceding section) suggests that Cassin's Auklets in British Columbia are a single designatable unit.

Special Significance

Canada (British Columbia) supports 75-80% of the global breeding population of Cassin's Auklets (Table 1). Cassin's Auklets represent 48% of the total population of nesting seabirds in British Columbia (McFarlane Tranquilla *et al.* 2007).

Table 1. Regional estimates of Cassin's Auklet breeding populations.

Region	Number of nesting individuals	Number of colonies[a]	Sources
Alaska	370,490 [b]	58	USFWS 2013
British Columbia	2,688,912	62	Rodway 1991; Harfenist 1994; Gaston and Masselink 1997; Regehr *et al.* 2007; Carter *et al.* 2012
Washington	88,104 [c]	7 [c]	Speich and Wahl 1989
Oregon	70 [d]	4 [d]	Kocourek *et al.* 2009
California [e]	41,544 [f]	16	Carter *et al.* 1992; Warzybok *et al.* 2004; Adams 2008; Cunha 2010; Whitworth *et al.* 2012
Baja California [e]			Carter *et al*. 2006a, b; Wolf *et al.* 2006; María Félix- Lizárraga, *pers. comm.*
P. a. aleuticus	> 61,400 [f]	5	
P. a. australis	> 75,334 [g]	3	

[a] Extirpated colonies are not included.

[b] Total includes colony estimates of 343,540 breeding individuals and 27,350 total individuals; estimates not available for some colonies.

[c] As many as 20,000 additional birds could be nesting in Washington at other sites (Speich and Wahl 1989).

[d] Results presented are from 1988 surveys; later surveys used methods known to underestimate burrow nesting birds.

[e] Recent research results suggest that auklets from southern California and Baja are *P. a. australis* (Wallace *et al.* in press).

[f] Estimates of "small numbers" are not incorporated into total.

[g] Estimates for islands from which introduced predators have been eradicated are not available.

Cassin's Auklet is a priority indicator species for the Canadian Wildlife Service (Gebauer 2003) and is monitored by Gwaii Haanas National Park Reserve/Haida Heritage Site as an indicator of the health of the shoreline ecosystem (Sloan 2007). It is also an indicator species being used by the Hesquiaht, Ahousaht and Tla-o-qui-aht First Nations to monitor impacts of climate change (Lerner 2011).

Aboriginal Traditional Knowledge and Significance to First Nations

Cassin's Auklet is one of several seabird species that were incorporated into the diet of Aboriginal peoples along the coast of British Columbia. According to traditional knowledge and evidence from midden excavations, Cassin's Auklet adults and eggs were taken on Haida Gwaii (e.g., Blackman 1979; Ellis 1991; Szpaka *et al.* 2009). The species was predominant in the diet, along with Ancient Murrelet (*Synthliboramphus antiquus*) and waterfowl, according to Haida elders (Blackman 1979; Ellis 1991). Cassin's Auklet remains were the most commonly recovered birds during excavations, indicating their importance as a resource over a long time period (Fedje and Mathewes 2005). At one midden site in southern Haida Gwaii, about 39% of the bird remains found were Cassin's Auklets (Fedje *et al*. 2001). Small alcids were also reported by Acheson (1998) from archaeological excavations in southern Haida Gwaii; most of those small alcids were later identified as Cassin's Auklet (R. Wigen, *pers. comm.*).

Cassin's Auklets were hunted even though they were smaller, less abundant, harder to hunt and more difficult to pluck than Ancient Murrelets (Ellis 1991). The adults were available later in the season than those of Ancient Murrelets because auklet nestlings develop in the burrow.

Traditional use of seabirds and eggs by the Kwakwaka'wakw People and North Tsimshian People is reported, but identification to species is not provided (Stewart and Stewart 1996; http://en.wikipedia.org/wiki/Kwakwaka'wakw).

Evidence from middens indicates that Cassin's Auklets were taken by Aboriginal People from the Aleutian Islands to southern California (e.g., Porcasi 1999; Pirie-Hay 2011).

Moss (2007) documented use of seabirds by Haida, Tlingit and their ancestors based on excavations on the Forrester Islands, Alaska, just north of the Canada/U.S. border, and noted that Cassin's Auklet was one of the most heavily used species. Heath (1915) also reported that Cassin's Auklets were an important food source on Forrester Island.

DISTRIBUTION

Global Range

The pelagic distribution of Cassin's Auklet is shown in Figure 2. The birds breed on islands from Buldir Island in the western Aleutian Islands, Alaska, to central Baja California in Mexico, with a gap between Kodiak Island and Prince William Sound, Alaska (Figure 1); they are occasionally reported from Siberia and the Kuril(e) Islands, Japan/Russia (Gaston and Jones 1998; Ainley *et al.* 2011).

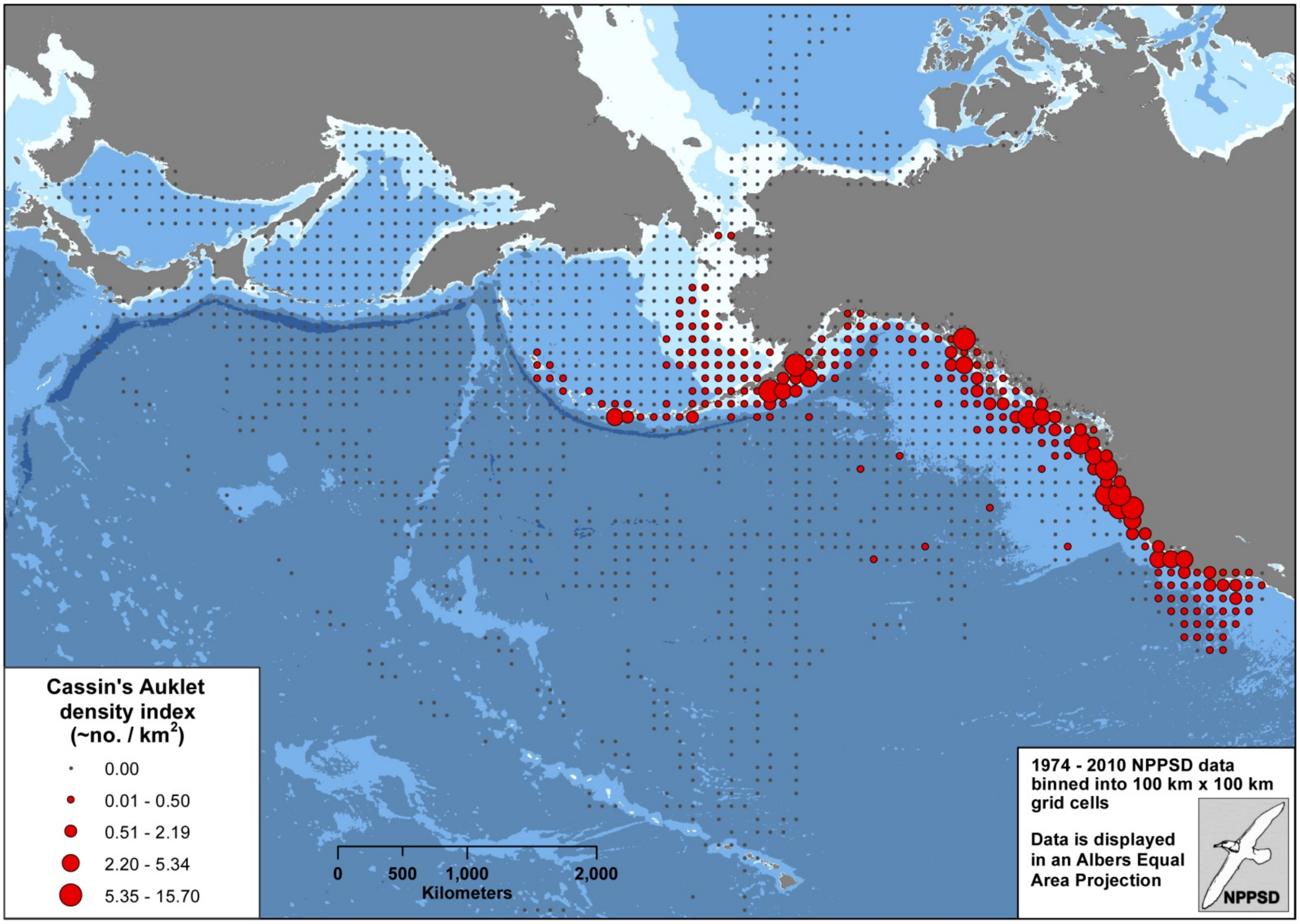

Figure 2. Pelagic distribution and abundance of Cassin's Auklet mapped from data held in the North Pacific Pelagic Seabird Database (Drew and Piatt 2013).

The present breeding range approximates that described in the 19th century (Ainley *et al.* 2011). Cassin's Auklets formerly occurred in small numbers farther west in the Aleutians around the Near Islands (Clark 1910, *cited in* Springer *et al.* 1993). Within their range, numerous colonies have been extirpated (e.g., Springer *et al.* 1993; Wolf *et al.* 2006); breeding populations have become re-established at some of those islands (Regehr *et al.* 2007; Whitworth *et al.* 2012; M. Félix-Lizárraga, *pers. comm.*).

Cassin's Auklets spend most of the non-breeding season at sea where their range is poorly described. In a recent review, Ainley *et al.* (2011) stated that northern breeders move south while those from central California remain year-round. They are reported from southeast Alaska south to Baja California (e.g., Briggs *et al*. 1987; McKibbin 2013b). Bird numbers are likely much reduced from the western and central Aleutian Islands and from the Gulf of Alaska in winter (USFWS 2006; Renner *et al.* 2008).

Canadian Range

Cassin's Auklets nest on 62 islands or island groups along coastal Haida Gwaii, the north and west coasts of Vancouver Island and the northern mainland coast (Figure 3). As noted above, 75-80% of the global population nests in British Columbia.

The Canadian breeding range has contracted slightly over the last century with the extirpation of colonies on Langara Island in northwest Haida Gwaii and Seabird Rocks off southwest Vancouver Island. The birds have re-established the Langara colony within the last two decades following the eradication of rats (*Rattus* spp.) from the site (Regehr *et al*. 2007). A colony on Glide Islands may represent a range expansion northward since 1988, but it is possible that this small colony was missed during earlier surveys (M. Lemon, *pers. comm.*).

The marine range of Cassin's Auklets can be described in only general terms because surveys have covered a small percentage of Canada's ocean waters (Kenyon *et al.* 2009). The birds are found throughout much of the Canadian Pacific (Figure 2). There are only scattered records of birds from the Strait of Georgia (Campbell *et al.* 1990). Cassin's Auklet density estimates based on at-sea surveys within 150 km of the coast during breeding (15 March – 31 July) and non-breeding (1 August – 14 March) seasons are shown in Figures 4 and 5, respectively. These estimates were generated by analyzing distribution and abundance data using a Kernal Density Smoothing function (see Nur *et al.* 2011a and Sydeman *et al.* 2012 for discussion of methods).

Cassin's Auklets are not found as inland vagrants (Gaston and Jones 1998).

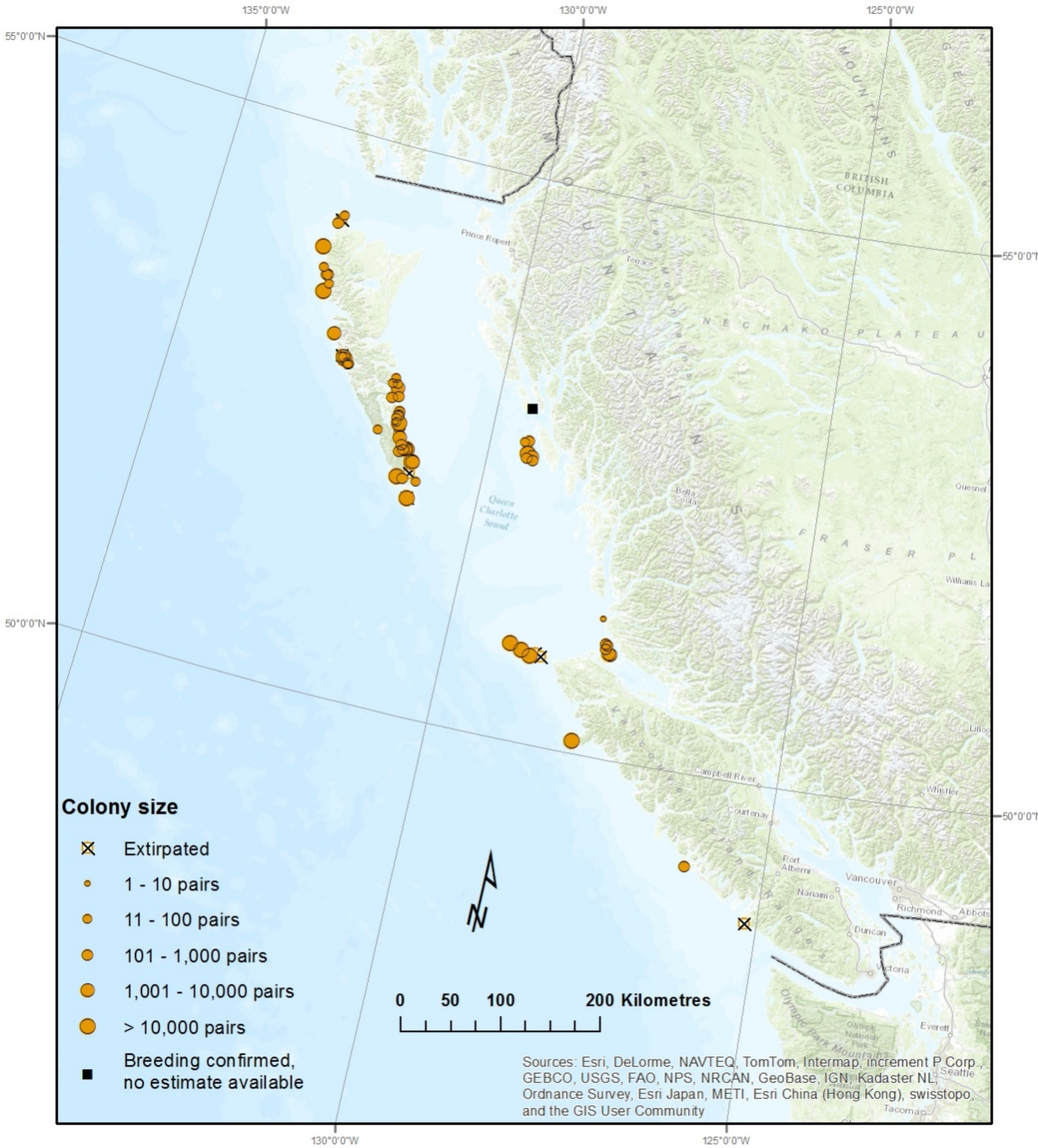

Figure 3. Locations and relative sizes of colonies of Cassin's Auklet in British Columbia.

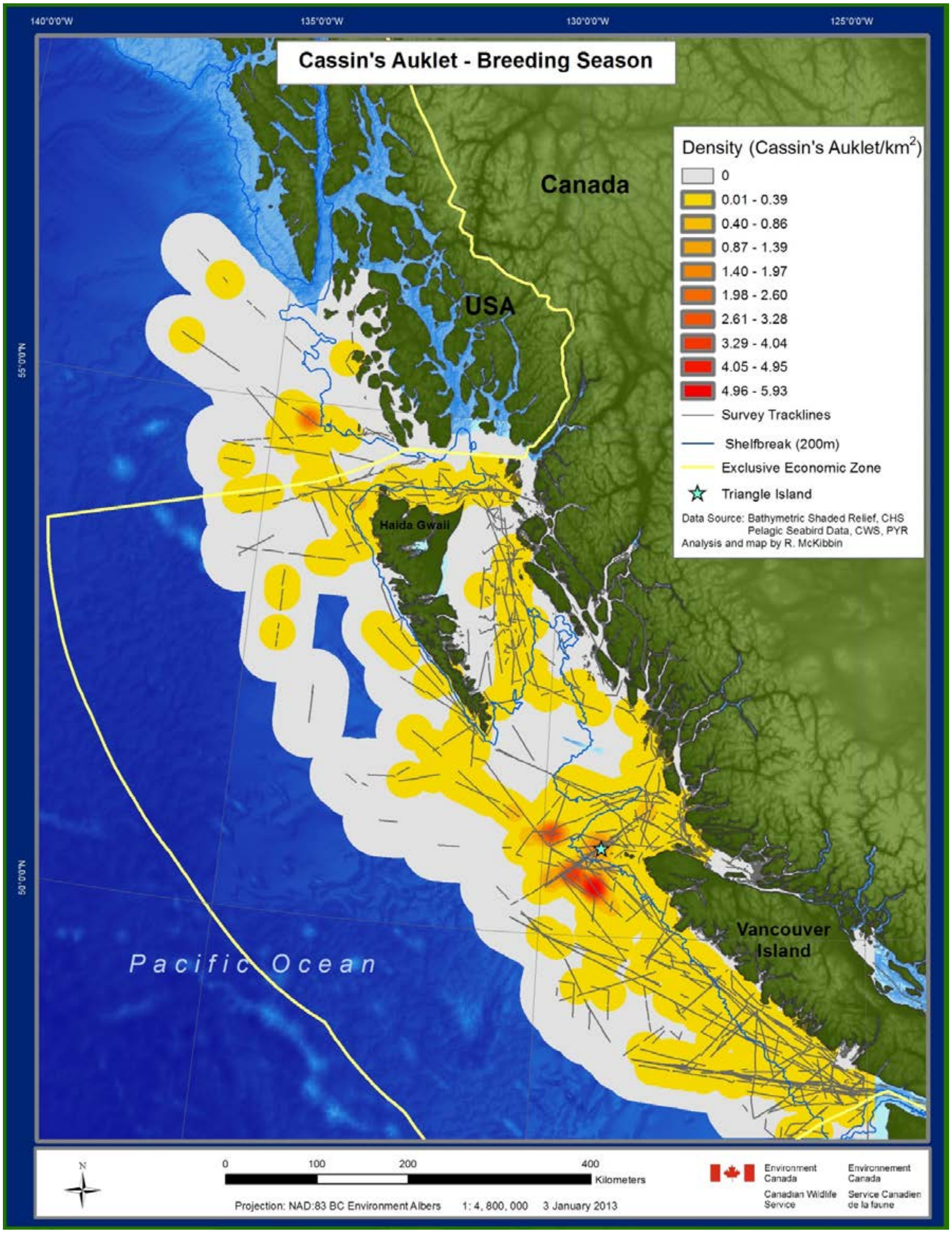

Figure 4. Marine densities of Cassin's Auklet within 150 km of land during the breeding season (15 March – 31 July) in British Columbia (McKibbin 2013b).

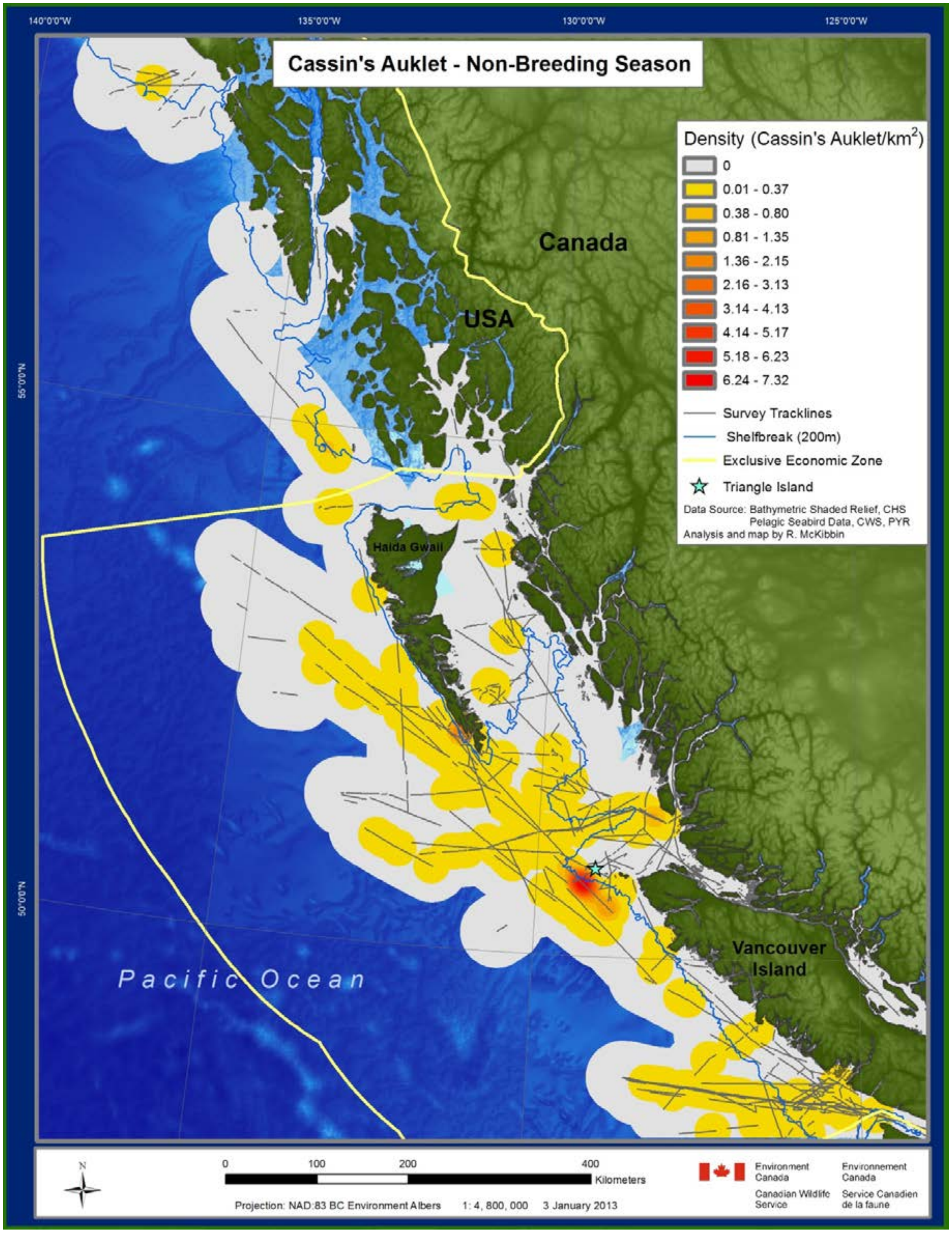

Figure 5. Marine densities of Cassin's Auklet within 150 km of land during the non-breeding season (1 August – 14 March) in British Columbia (McKibbin 2013a).

Extent of Occurrence and Area of Occupancy

Extent of occurrence and area of occupancy for Cassin's Auklet in Canada were both calculated based on the location (spatial coordinates) of extant colonies (A. Filion, *pers. comm.*). The estimated extent of occurrence is 67,000 km^2, calculated as a minimum convex polygon. The index of area of occupancy is 228 km^2, calculated as the number of 2x2 km grid cells intersecting the coordinates of Cassin's Auklet colonies. One additional grid cell was incorporated into the index because two grid cells are required to properly represent the colony on Triangle Island.

Search Effort

Breeding colonies were identified through an extensive exploration of coastal islands during the 1980s (Rodway *et al*. 1988, 1990a, b, 1994; Rodway and Lemon 1990, 1991a, b). A total of 390 islands or island groups with potential seabird habitat were surveyed. An additional 67 islands, suspected of supporting nesting seabirds based on reports from the 1970s by the B.C. Provincial Museum, were not resurveyed in the 1980s. The Museum surveys, which had been designed to identify the presence of nesting seabirds, indicated that Cassin's Auklets were nesting at 6 of those 67 islands. Both sets of surveys were general, targeting all seabird species. The combined results from this two-decade long inventory forms the basis for the estimated Canadian nesting population of Cassin's Auklet.

For 59% of the identified Cassin's Auklet colonies, the number of breeding pairs was estimated from standardized sampling methods, or total or partial counts. Estimates for the remainder, comprising about 10% of the total breeding population, have no associated confidence limits. Few islands have been resurveyed since the 1980s, so any potential change in range will have gone largely undetected.

At-sea population estimates are not available. Cassin's Auklets are recorded during ship-based surveys for pelagic marine birds, but those surveys cover only a small percentage of Canada's Pacific Ocean (Kenyon *et al.* 2009). Furthermore, most surveys are conducted on ships-of-opportunity and the routes are not under the control of the seabird observers. The methods and their potential biases are described in Morgan *et al.* (1991). Observations from a variety of sources are summarized in Campbell *et al.* (1990); coverage is uneven and biased toward more accessible marine areas.

TERRESTRIAL NESTING HABITAT

Terrestrial Habitat Requirements

Cassin's Auklets nest on offshore islands in burrows, caves or crevices, or under driftwood or debris (e.g., Ainley *et al*. 2011). Islands may be forested or treeless. A primary habitat requirement for the establishment of a colony at a site by Cassin's Auklets is that the island be free of most mammalian predators, including rats, Common Raccoon (*Procyon lotor*) and American Mink (*Neovison vison*). The presence of native mice, which depredate unattended eggs, does not preclude nesting by Cassin's Auklets (Ronconi and Hipfner 2009).

In British Columbia, the vast majority of Cassin's Auklets nest in excavated burrows (e.g., Vermeer *et al*. 1979, 1997), whereas in California, nesting habitat shifts from primarily burrows in the north to primarily crevices in the south (Carter *et al.* 1992). In 280 surveyed plots on islands in Haida Gwaii, about 25% were in forested habitat with a mossy or bare floor, 20% were in forested habitat with grass, 25% were in non-forested areas with grass, and the remainder were scattered across 10 habitat types (G. W. Kaiser, *pers. comm*., *cited in* Vermeer *et al*. 1997). On Frederick Island, Haida Gwaii, birds nested mainly under Sitka Spruce (*Picea sitchensis*) and Western Hemlock (*Tsuga heterophylla*) in grass tussocks or moss; burrows were also found under tree roots, stumps and fallen logs (Vermeer and Lemon 1986). Most burrows were within 100 m of the shoreline. On treeless Triangle Island, the largest Cassin's Auklet colony in the world, the preferred burrow location is beneath Tufted Hairgrass (*Deschampsia cespitosa*), whereas areas dominated by Tall Salmonberry (*Rubus spectabilis*) are avoided (Vermeer *et al.* 1979); the birds commonly nest in fern habitat as well (Rodway *et al.* 1990b).

In Washington, Cassin's Auklets nest under the open Salal (*Gaultheria shallon*) and salmonberry shrub layer as well as under trees (Speich and Wahl 1989). On the Channel Islands in southern California, burrows are found associated with cacti (*Opuntia* sp.) and Alkalai Heath (*Frankenia salina*) (Ainley *et al*. 2011). The birds also nest under cacti farther south on San Benitos Island in Baja California (Ainley *et al*. 2011).

Use of terrestrial habitats outside the breeding season has not been documented for British Columbia. In contrast, Cassin's Auklets have been reported roosting and interacting on the Farallon Islands in California during the non-breeding season (Ainley *et al.* 1990).

Terrestrial Habitat Trends

Two main trends in terrestrial habitat have been described for Cassin's Auklet across its range: alienation of nesting habitat due to introduced species and changes in vegetation. Loss of habitat due to the introduction of non-native predators has historically been the most notable trend. The extent of loss is not well documented as rigorous surveys prior to the introductions are usually lacking.

In Haida Gwaii, depredation by rats and raccoons is the likely cause of extirpation of nesting Cassin's Auklets on Langara, Cox, St. James and Saunders islands (Harfenist and Kaiser 1997). The predators have also greatly reduced the number of breeding auklets at four other colonies in the archipelago. The extirpation of Cassin's Auklet on Lanz Island, off northwest Vancouver Island, has been attributed to introduced mink, and mink, along with raccoons, are likely responsible for the loss of nearby Cox Island as a breeding colony (Rodway *et al.* 1990b).The recent extirpation of the Cassin's Auklet colony on Seabird Rocks, off southwest Vancouver Island, was apparently due to predation by Northern River Otter (*Lontra canadensis*; Carter *et al.* 2012).

The trend of habitat loss due to introduced species has been reversed over the last few decades with a management focus on removing invasive species. In Haida Gwaii, rats were eradicated from Langara, Cox and St. James islands in the late 1990s (Kaiser *et al.* 1997; Golumbia 2000) and raccoons have been eliminated from several islands (Harfenist *et al*. 2002). However, these islands might be best considered temporarily raccoon-free, because the mammals remain on nearby potential source islands.

A decrease in high-quality nesting habitat due to changes in vegetation has been described on the two largest Cassin's Auklet colonies in British Columbia. On Triangle and Sartine islands, Tufted Hairgrass cover declined while salmonberry cover increased between the late 1980s and mid-2000s (Hipfner *et al.* 2010a). Thus, there has been a shift from the habitat preferred by auklets to a habitat that is avoided by the birds. There is evidence suggesting that the change on Triangle may have been occurring over a longer time frame, possibly since the 1950s. Rodway and Lemon (2011) reported loss of burrowing habitat due to windfall and dense regeneration of Sitka Spruce on two islands in Haida Gwaii.

MARINE HABITAT

Marine Habitat Requirements

The main current systems of the northeast Pacific Ocean form the background for much of the discussion of Cassin's Auklet biology and population trends. Briefly, the North Pacific Current bifurcates off the coast of British Columbia and forms the Alaska Current to the north and California Current to the south (Figure 6). The Alaska Current System is a downwelling zone, whereas the California Current System is an upwelling domain; a transition zone lies between the two. The latitudinal location and range of the bifurcation varies between years; its usual latitude is around 45^{o}N (Batten and Freeland 2007).

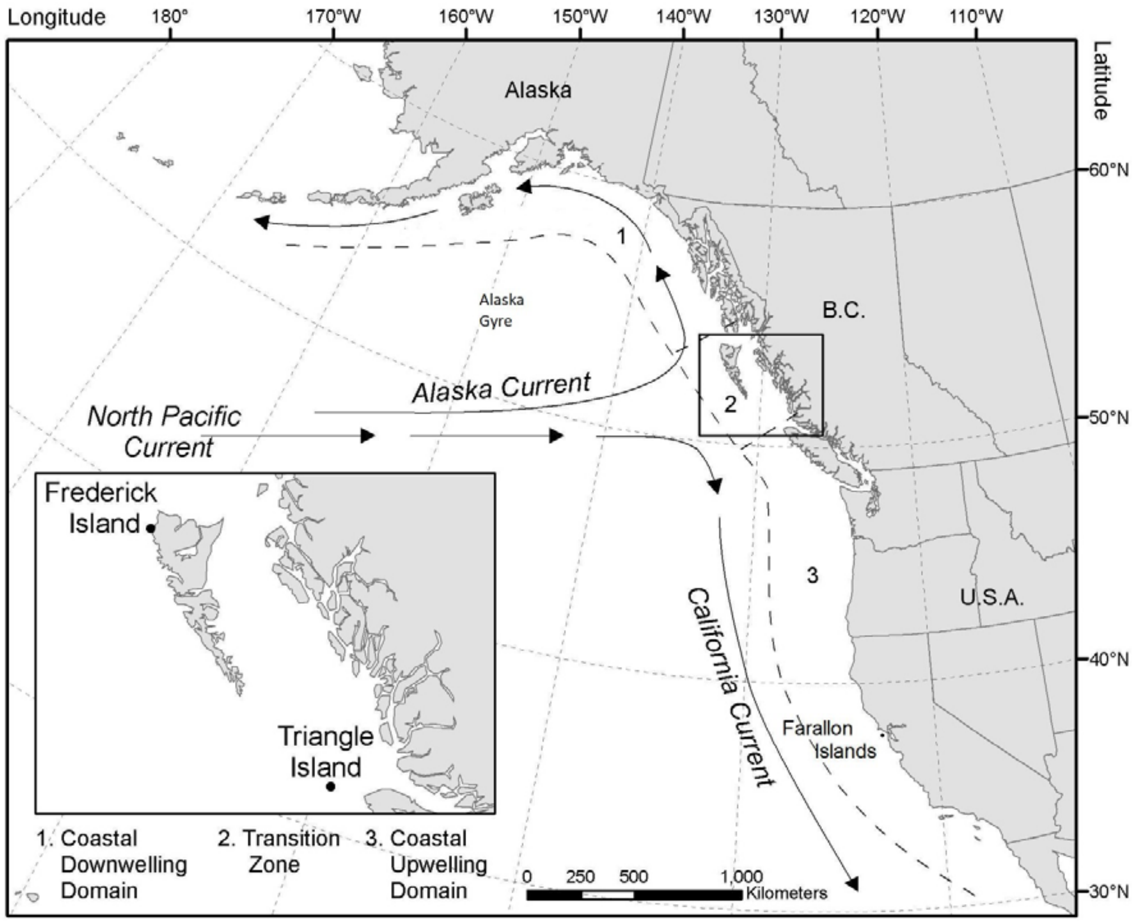

Figure 6. Major currents and oceanographic domains in the northeast Pacific Ocean (adapted from Bertram *et al.* 2009).

Cassin's Auklets use marine areas where bathymetric features promote marine productivity (Gebauer 2003). In British Columbia, Cassin's Auklets are found primarily over the continental shelf break (200 m isobath) and slope region (west of the shelf break); they are occasionally observed far offshore (Kenyon *et al*. 2009). Off northwestern Haida Gwaii during the breeding season, the birds are associated with the shelf break as well as with seamounts and banks (Vermeer *et al.* 1985). At Triangle Island, Hipfner *et al.* (2014) found that the birds' foraging habitat varied within the breeding season. Prior to egg laying, auklets tended to forage in inshore waters, and foraging moved progressively farther offshore through the nestling provisioning stage. Cassin's Auklets are associated with the continental shelf break in Washington and California as well; in California they are also found near coastal promontories and over underwater canyons (Speich and Wahl 1989; Adams 2008). Nur *et al.* (2011a) reported that the strongest predictor of Cassin's Auklet abundance in the California Current System is a contour index that reflects the topographic relief of the sea floor. Distance to the 1000 m isobath (related to proximity to the shelf slope) was also a strong predictor.

The summer and winter ranges of Cassin's Auklets are delimited by average ocean surface temperatures of 9-20^o and 6-20^o C, respectively (Gaston and Jones 1998).

The marine waters from northwest Vancouver Island to southern Haida Gwaii incorporate three of six areas in the California Current System of consistently elevated abundance of Cassin's Auklets: south Haida Gwaii, Queen Charlotte Sound and Triangle Island (Sydeman *et al.* 2012). Nur *et al.* (2011a) found that the ocean waters off northwest Vancouver Island comprise one of only two areas in the California Current System of high predicted Cassin's Auklet abundance in February, immediately prior to breeding.

The at-sea distributions of birds radio-tagged at Triangle Island varied between years (Boyd *et al*. 2008). During the period when they were provisioning nestlings at the colony, adults were found about 50 km from the island in waters 1,400-1,800 m deep in 1999-2000 and about 80 km from the island in waters 725 m deep in 2001. The marine area used by Cassin's Auklets also varied between years from 650-1,400 km^2 to 3,200-8,200 km^2 (50% and 95% kernel home range, respectively; see Boyd *et al.* 2008 for details). The calculated ranges did not include travel corridors.

Cassin's Auklet density at sea is positively associated with zooplankton abundance along the coast of British Columbia (Sydeman *et al.* 2010). Near Triangle and Frederick islands, their distribution during the breeding season is associated with areas of high concentrations of copepods (Vermeer *et al*. 1985; Hedd *et al.* 2002). Similarly, in California, Cassin's Auklet distribution was associated with that of euphausiids (Santora *et al.* 2011). Lovvorn (2010) modelled Cassin's Auklet foraging in relation to prey patch and suggested that there may be an upper limit to the relationship between auklet dispersion and prey patch density that is relatively low compared to the densities of prey that occur. He noted, however, that other factors such as patch visibility or predictability may be important.

Discussions of influences of ocean factors on the distribution and abundance of the birds' zooplankton prey are available (e.g., Tanasichuk 1998; Batten and Freeland 2007; Mackas *et al.* 2007). The oceanography of the northeast Pacific off the British Columbia coast is described in detail in Thomson (1981) and Lucas *et al.* (2007).

Cassin's Auklets are found in the following marine ecoregions: Aleutian Archipelago, Alaskan/Fjordland Pacific, Columbian Pacific, Montereyan Pacific Transition, Southern Californian Pacific (Morgan *et al.* 2005). The Canadian population is within the Alaskan/Fjordland Pacific and Columbian Pacific Ecoregions.

Marine Habitat Trends

Conditions in the northeast Pacific Ocean fluctuate over multiple time scales. Seasonal, short-term and intermediate-term cyclical variations, as well as a long-term trend toward warming ocean water, have been described (e.g., Harley *et al.* 2006; Mackas *et al*. 2007; Irvine and Crawford 2012). Sydeman *et al.* (2009) discussed the difficulty of separating the manifestations of cyclical variations from those of trends in the ocean environment.

Seasonal changes in abiotic factors such as currents, upwelling, salinity and water temperature affect abundance and distribution of marine species (e.g., Irvine and Crawford 2012). Mackas *et al.* (2012) noted that seasonal variability in biomass of 50 zooplankton species off the coast of British Columbia is strong and somewhat cyclical. Key zooplankton availability shifts over the Cassin's Auklet nesting season in British Columbia (e.g., Hedd *et al.* 2002; Bertram *et al.* 2009; Hipfner 2009).

El Niño/Southern Oscillation (often referred to as El Niño or ENSO) events involve a poleward movement of warm water from the tropics that lasts for 1 to 2 years. The oscillation describes shifts between El Niños, characterized by warming sea surface temperatures and reduced productivity, and La Niñas, associated with colder waters and increased productivity (e.g., Legaard and Thomas 2006). The periodicity of El Niño events is about 3 to 7 years; the frequency has increased over recent decades (McGowan *et al*. 1998; DFO 2012).

In spring and summer 2005, another type of short-term climate event affected ocean conditions in the central and northern portions of the California Current System. An anomalous atmospheric blocking event caused warm sea surface temperatures, reduced upwelling and a decline in zooplankton biomass (Mackas *et al*. 2006; Sydeman *et al*. 2006).

The Pacific Decadal Oscillation (PDO) is characterized by warm water periods alternating with colder water periods at a 20-30 year time scale (Latif and Barnett 1996; Francis *et al*. 1998). The transitions between phases are associated with shifts in primary and secondary productivity. The northeast Pacific Ocean was in a warm water phase of the PDO from 1976/77 through 1999 (Mackas *et al.* 2001). A cold water phase of the PDO may have begun in 2008 (Hatch 2013).

Variability in ocean climate is linked to changes throughout the marine ecosystem. There are similarities in abiotic and biotic changes observed during warm water phases of the PDO and El Niños (Francis *et al.* 1998; Mantua and Hare 2002). Nutrient supply and primary production declined during strong El Niños and the beginning of the 1977-1998 PDO (McGowan *et al.* 2003). Of direct importance to Cassin's Auklets are changes to the zooplankton communities. Mackas *et al*. (2012) showed the large degree of variability in seasonal timing and biomass of the zooplankton community in British Columbia's waters from 2000-2011. Two main responses to warm water conditions are described: poleward shifts in abundance and earlier and narrower peaks of *Neocalanus plumchrus* biomass (Mackas *et al.* 2007; Batten and Mackas 2009). As a result of the spatial shift, the abundance of larger, more nutritious, sub-arctic copepods is lower in warm water years; the change to the zooplankton community affects predators including planktivorous seabirds, like Cassin's Auklet (DFO 2012).

Large-scale climatic events like ENSOs and PDOs may affect the entire range of Cassin's Auklet. There is, however, considerable local variation in the magnitude of observed effects (Wolf *et al.* 2009). Whereas PDOs tend to be more severe in the north Pacific than near the tropics, ENSOs show the reverse pattern. During the atmospheric blocking event of 2005, the area from southern British Columbia to northern California was the most affected (Mackas *et al.* 2006).

In addition to the cyclic patterns described above, there has been a warming trend in the ocean waters of the California Current System and Alaska Gyre over the last 50 years (e.g., Thompson *et al*. 2012). The warming trend has been accompanied by declines in primary productivity and zooplankton biomass in the California Current (McGowan *et al.* 1998). There is evidence that the timing of peak biomass of *N. plumchrus* has advanced by more than 5 weeks over 30 years in the northern California Current System (Mackas *et al.* 2007). Thompson *et al*. (2012) found that the timing of chlorophyll blooms in the Alaska Gyre shifted earlier in the spring and later in the fall, resulting in an extended plankton growing season; no change in amplitude of peak blooms was observed.

Variability and trends in ocean climate in British Columbia are summarized annually in DFO State of the Oceans Reports (e.g., Irvine and Crawford 2012).

BIOLOGY

The biology of Cassin's Auklet has been recently reviewed (Ainley *et al*. 2011). An earlier review (Gaston and Jones 1998) includes additional details on aspects of the species' biology in British Columbia. When considering the information presented in the following sections, it is important to keep in mind that the vast majority of Cassin's Auklet studies have been conducted at two colonies: Triangle Island in British Columbia and the Farallon Islands in California (Figure 6). These colonies are located more than 1000 km apart in the California Current System and have extensive time series data. More limited data available from Frederick Island, which lies in the Alaska Current System, provide evidence that some aspects of the species' biology differ markedly between systems. Thus, study location is noted in the sections below.

Although the discussion focuses on information from British Columbia, results from California are incorporated if corresponding data are not available in Canada or to show the system-wide scale of effects of ocean climate on Cassin's Auklet. Patterns observed across the California Current System provide support for extrapolation of Triangle Island trends to other British Columbian colonies in the same oceanographic domain.

Life Cycle, Reproduction and Demography

Cassin's Auklets spend most of the year at sea and come to land during the breeding season to nest. They are colonial breeders and are nocturnal in their visits to the colony.

Cassin's Auklet pairs lay a single-egg clutch, which is incubated by both parents on alternating days for approximately 38-39 days (Manuwal 1974; Ainley *et al*. 1990). On the Farallon Islands, incubation ranged from 37-57 days (Ainley *et al*. 1990). Replacement eggs may be laid if an egg is lost (Ainley *et al.* 1990; Hipfner *et al.* 2004). At the Farallon Islands, pairs may lay a second clutch after successfully fledging a first chick in some years (Ainley *et al*. 1990); double clutches have not been reported at any other colony.

Nestlings are brooded by a parent for 3-6 days, after which they are usually left alone in the burrow during the day, with parents returning to feed them at night. The nestling period lasts about 45-46 days (A. Harfenist and Y. Morbey, *unpubl. data, cited in* Gaston and Jones 1998). On Frederick Island, the nestling period ranged from 41-54 days (A. Harfenist, *unpubl. data, cited in* Gaston and Jones 1998). Chicks are independent at fledging.

Cassin's Auklet demographic parameters are summarized in Table 2. Many of those parameters exhibit extensive inter-colony and/or inter-annual variability that has been related to ocean conditions (e.g., Bertram *et al*. 2005; Hipfner 2008; Hipfner *et al.* 2010b; Morrison *et al.* 2011).

Table 2. Demographic parameters for Cassin's Auklet. Estimates are provided for British Columbia where available; Canadian data are supplemented with values from the Farallon Islands, California.

Parameter	Value	Location	Notes	Source
Sex ratio	1:1	Farallon Is.		Pyle 2001; Lee *et al.* 2007
Age at first breeding	3.3 years	Farallon Is.	1981-1999	Pyle 2001
	3.6 years		2000-2009	Lee *et al.* 2012
Proportion of mature birds breeding	20% of floating population composed of birds that had previously bred	Farallon Is.		Manuwal 1974
Clutch size	1	range-wide		Ainley *et al.* 2011
Number of clutches/year	1 2	range-wide Farallon Is.		Ainley *et al.* 2011
Reproductive success (chicks fledged/egg hatched)	47- 93%	Triangle I.	1994-2000	D. Bertram, *unpubl. data*
	94-99%	Frederick I.	1994-1998	A. Harfenist, *unpubl. data*
Fecundity	63%	Farallon Is.	high inter-annual variability	Nur *et al*. 2011b
Recruitment	36% mean for birds > 3 years of age	Farallon Is.	age-specific	Lee *et al*. 2012
Annual adult survival	males - 75% females - 84%	Triangle I.	1994-2008 1994-2008 excluding 1998 & 2005 [a]	Morrison *et al.* 2011
	females - 44%		1998 & 2005 [a]	
	80%	Frederick I.	1994-2000	Bertram *et al.* 2005
	71%	Triangle I.		
	86%	Reef I.	1985-1991	Gaston 1992
Generation time	7 years (range 6.2-8.1 years)		estimated using range of survival values from B.C.; assumed age at first breeding = 3 years and fecundity within ranges found on the Farallon Islands.	IUCN 2011 spreadsheet file (Generation length.xls)

[a] 1998 and 2005 were years of extreme climate events.

A high degree of nest site fidelity between years has been shown on Frederick Island (A. Harfenist, *unpubl. data, cited in* Gaston and Jones 1998) and on the Farallon Islands (Manuwal 1974; Pyle *et al.* 2001). On Frederick Island, in the year following initial marking of pairs in 40 burrows, 65% of burrows contained the same pair and 15% had one of the marked birds with a new partner due to death of, or divorce from, the original mate. Natal philopatry was apparently strong on the Farallon Islands (Pyle 2001). However, as noted by Ainley *et al.* (2011), the nearest alternative nesting sites are several hundred kilometres from the Farallons. Birds fledged from Canadian colonies, which tend to be in relatively close proximity to each other, may not show the same degree of natal philopatry.

Phenology

In general, the timing of nesting varies with latitude, with earlier breeding at southern latitudes. In Haida Gwaii, birds nesting on the southeast coast were more than two weeks earlier than those on the northwest coast; at the former site, median dates of hatching were April 28-May 2 (Vermeer *et al*. 1997). At Triangle Island, mean hatch date varied between May 8 and May 30 in 1994-2011, with the first egg laid consistently in late March/early April (Hipfner *et al*. 2010b). Vermeer *et al.* (1997) reported that nesting on Frederick Island was several weeks earlier in the mid-1990s than in the early 1980s. Although Bertram *et al.* (2001a) did not detect a significant advance in timing of breeding on Triangle Island from 1975 to 1999, they did note extreme variation in timing during the 1990s.

Inter-annual variation in timing of breeding has been related to oceanic conditions. Hipfner *et al*. (2010b) found that lay dates tend to be more synchronous in cold water years, which has the effect of advancing the median date of laying in those years. A positive correlation between hatching dates and sea surface temperature was also reported at the Farallon Islands (Ainley *et al*.1990; Abraham and Sydeman 2004).

Reproduction

Reproductive performance is well studied at two colonies in British Columbia and two patterns that emerge from the results are: 1) inter-annual fluctuations in reproductive parameters related to ocean conditions and 2) higher and more consistent reproductive success at Frederick Island than at Triangle Island.

Inter-annual variation in reproductive success is well documented at Triangle Island and has been related to ocean climate through impacts on the birds' prey (e.g., Bertram *et al.* 2009; Hipfner 2009). Nestling growth and survival (from hatch to fledge) was positively correlated to the proportion of *Neocalanus cristatus* in the diet (Bertram *et al.* 2001a; Hedd *et al*. 2002; Hipfner 2009). The key factor appears to be the degree of overlap between the nestling provisioning period and the period of availability of *N. cristatus:* chick growth is poor when the timing of predator and prey are mismatched (Bertram *et al.* 2001a). In colder water years, the timing of peak *N. cristatus* biomass is later and more prolonged, whereas in warmer water years the peak advances and is of shorter duration (Mackas and Galbraith 2002; Batten and Mackas 2009) causing a temporal mismatch with the birds' nesting cycle (Bertram *et al.* 2009; Hipfner 2008). As a result of the mismatch, in warmer water years nestling growth is depressed and the chicks fledge at lighter masses (Hipfner 2009). Hipfner (2008) found that about 80% of the inter-annual variation in nestling growth and survival was explained by the proportion of *N. cristatus* in the diet and noted that seasonal timing of *N. cristatus* was more important than its abundance.

Many of the warm water years in the above studies were associated with El Niño events. The 2005 atmospheric anomaly also resulted in warmer water and associated zooplankton shifts (Sydeman *et al*. 2006). The low reproductive success on Triangle Island (8%) in 2005 was attributed to a mismatch between predator and prey. On Triangle Island, nestling growth rates have predominantly been positive since 2008 when the PDO may have shifted to a cold water phase; the exception was during the 2010 El Niño (Hipfner 2012).

Frederick Island, located in a different ocean current domain, shows different responses to ocean climate variability. In contrast to the high variability found on Triangle Island, reproductive success on Frederick Island was relatively stable during the late 1990s (Bertram *et al*. 2001b). Nestling growth and mass at fledging were comparatively higher than those at Triangle Island during all years of the study (D. Bertram and A. Harfenist, *unpubl. data*). In 2000, when ocean temperatures had cooled, the nestling growth rates at the two islands were similarly high (Bertram *et al.* 2001b). In 2005, when Cassin's Auklets throughout the California Current System experienced very poor reproduction (Sydeman *et al.* 2006), reproductive success was normal on Frederick and Rankine islands in the Alaska Current System (M. Hipfner and M. Lemon, *pers. comm., cited in* Bertram *et al.* 2009). Bertram *et al.* (2009) noted that temporal mismatches between prey availability and the nestling provisioning period did not occur on Frederick Island. During the 1998 El Niño, the peak of *N. cristatus* was later and more prolonged at Frederick Island compared to Triangle Island and the zooplankton were available throughout the nestling period.

A relationship between ocean climate, zooplankton prey and Cassin's Auklet reproductive success has also been well described on the Farallon Islands (e.g., Abraham and Sydeman 2004; Lee *et al.* 2007). Again, reproductive success is reduced in warm water years.

Survival

Survival estimates for Cassin's Auklets are based on capture-mark-recapture models in which permanent emigrants from the population (i.e., birds that leave the area being studied) are treated as deaths. Thus, the estimates correspond to local survival.

The longest time series data on annual adult survival in British Columbia is from Triangle Island during 1994-2008, a time period that included a strong El Niño in 1997/98 and an atmospheric blocking event in 2005 (Morrison *et al.* 2011). Annual adult survival for females was 84% in years excluding the two major climate events and 44% during those events. Male survival remained at 75% throughout the study.

Annual adult survival estimates from Frederick Island during 1994-2000 were significantly higher than those from Triangle Island over the same years (Bertram *et al.* 2005). Survival fell significantly at both colonies during the strong 1997/98 El Niño: from 80% to 64% at Frederick Island and from 71% to 54% at Triangle Island. Annual survival of sub-adults was lower than that of adults on Frederick Island.

Data from the Farallon Islands, California, clearly show the influence of ocean conditions on annual adult survival of Cassin's Auklet. Using data from 1986-2008, Nur *et al.* (2011b) estimated adult survival of 58% in years of major El Niño events and 64% in the first year of the 2005/06 oceanic anomaly compared to 79% in other years; survival was 77% overall. Birds aged 5-10 years of age had higher survival than those younger or older (Lee *et al.* 2012).

Recruitment, Fecundity and Breeding Propensity

Estimates for Cassin's Auklet recruitment, fecundity and breeding propensity are available for the Farallon Islands. Lee *et al*. (2012) reported both individual age and parental age effects on recruitment. The probability of recruitment increased rapidly for individuals aged 2-4 years and then declined slowly for older ages; birds up to 10 years of age were recruited into the breeding population. Lee *et al*. (2012) suggested that the lower recruitment probability for 2-year-old birds found in their study (19%) compared to that found in an earlier study at the same site (24-29%; Pyle 2001) may indicate a trend to delayed maturity. The study also demonstrated lower return rates for fledglings from younger female parents (ages 2-4 years) compared to those from older ones (ages 5-10 years); no age-specific relationship was found for male parents (Lee *et al*. 2012).

During 1986-2008, fecundity was 63% overall on the Farallon Islands (Nur *et al.* 2011b). Rates were related to ocean conditions: 37% in years of major El Niño events, 3% in the first year of the 2005/06 oceanic anomaly and 71% in all other years.

Breeding propensity on the Farallon Islands was lower in warm water years (Abraham and Sydeman 2004). Breeding propensity did not show age-related effects (Lee *et* al. 2012).

Generation Time

Estimates of generation time depend on demographic parameters that are either unknown or extremely variable for the Canadian population of Cassin's Auklets. Thus, the estimate of approximately 7 years (range 6.2 – 8.1), calculated using the IUCN (2011) spreadsheet file Generationlength.xls, should be used with caution. Values for age at first breeding (3-4 years) and fecundity (37-71%) were based on data from the Farallon Islands and may not reflect values for the Canadian population. Annual adult survival rates from Triangle and Frederick islands (see Table 2), used in the estimates, were assumed to remain constant with age. However, survival may be age-dependent in British Columbia, as it is on the Farallon Islands.

Diet

Cassin's Auklets are pursuit diving seabirds that forage primarily on copepods, euphausiids and larval fish (e.g., Vermeer 1985). There is little information on diet of adults during either the breeding or non-breeding season as most diet studies sample food items brought back to the colony by provisioning parents and, thus, describe nestling diet. Vermeer *et al.* (1985) reported that the stomach contents of adults was essentially identical to the prey being brought back to the colony at Frederick island and suggested that adults self-feed on the same prey that they collect for their young. In contrast, Davies *et al.* (2009) found that the diets of provisioning adults at Triangle Island were from a lower trophic level than the prey brought to nestlings. However, a subsequent study at Triangle Island (Hipfner *et al.* 2014) reported results consistent with those of Vermeer *et al.* (1985).

In British Columbia, nestling diets are best described for Triangle Island where annual mean occurrences of the three predominant prey types as percent of biomass over 11 years were the copepod *Neocalanus cristatus* (40%), euphausiids (mainly *Euphausia pacifica, Thyanoessa spinifera* and *T. inspinata;* 40%) and larval fishes (15%; Hipfner 2008). Bertram *et al*. (2009) compared nestling diet at Triangle and Frederick islands in 1978-1982 and the mid-1990s. They found that more than 89% of the diet at both sites in all years was composed of copepods and euphausiids. *N. cristatus* was the predominant prey item at both colonies. At Triangle Island, fish were a major prey item in warm water years, whereas, fish, which had been important in some years in the earlier time period at Frederick Island, were only a minor prey item for the birds in the 1990s. The primary fish prey were rockfish, but flatfishes (Pleuronectidae) and Irish lords (*Hemilepidotus* spp.) also contributed to the diet in some years. Carideans (shrimp and mysids), amphipods and brachyurans were also present in the diet.

The relative abundance of prey types in the diet varies between and within seasons and is related to ocean conditions (e.g., Hedd *et al.* 2002; Bertram *et al.* 2009; Hipfner 2009). Between 1996 and 2006, *N. cristatus* were less prevalent in the diet on Triangle Island in warmer water years and declined in the diet several weeks earlier in those years compared to colder water years (Hipfner 2008). The contribution of *T. spinifera* in the diet was related to sea surface temperature during spring of the previous year (Hipfner 2009). However, no relationship between the amounts of *E*. *pacifica* and *T. inspinata* in the diet and ocean climate were found.

Two studies at Triangle Island used stable isotope analysis to examine foraging ecology of Cassin's Auklet over the breeding season and found that the species shifted both diet and foraging habitat (Davies *et al.* 2009; Hipfner *et al.* 2014). Adults fed at lower trophic levels during incubation and nestling periods than earlier in the breeding season when more fish and crustaceans were present in the diet. In addition, the birds exhibited a progressive inshore to offshore shift in foraging habitat during the season from prior to egg-laying through the nestling stage.

Cassin's Auklet diet varies across the species' range. On the Farallon Islands, the diet is composed mainly of *E. pacifica* and *T. spinifera,* but when abundance of euphausiids is low, amphipods and mysids are eaten (Abraham and Sydeman 2004). Fish form a greater proportion of the diet in the Channel Islands, southern California (Adams 2008). In the Gulf of Alaska, the diet was primarily calanoid copepods but also included shrimp, fishes, squids, euphausiids, and gammarid amphipods (Sanger 1987).

Cassin's Auklets primarily forage in near-surface waters: the majority of dives are to depths of less than 15 m (Burger and Powell 1990; J. Adams, *unpubl. data, cited in* Ainley *et al*. 2011). At Reef Island in Haida Gwaii, maximum diving depths averaged 28 m, with a mode of 40 m (Burger and Powell 1990).

Physiology and Adaptability

Little is known about Cassin's Auklet nutrition and energetics. Hodum *et al.* (1998) measured field metabolic rates for adults provisioning nestlings and estimated a daily energy expenditure of 413 kJ.

Certain aspects of Cassin's Auklet behaviour have likely evolved as predator avoidance strategies. The birds nest on offshore islands that are largely free of native mammalian predators. Their nocturnal habit at the colony is considered an adaptation to avoid avian predators (e.g., Ainley *et al*. 2011). Adults and sub-adults arrive and depart in darkness; activity was reduced on bright moonlit nights when predation by gulls was heavier (Nelson 1989). Nestlings also fledge at night. In addition, Cassin's Auklets may adjust incubation behaviour to limit predation by endemic Keen's Mice (*Peromyscus keeni;* Ronconi and Hipfner 2009).

Nest site fidelity in this species is strongly developed (Manuwal 1974; A. Harfenist, *unpubl. data*). Cassin's Auklets do not seem to abandon their breeding attempts to move to a new colony when neighbouring adults or burrow contents have been depredated (Rodway *et al.* 1990b; Gaston and Masselink 1997).

Cassin's Auklets exhibit some behaviours that render them vulnerable to human activity. At night, they are attracted to light, which can cause injury or death near boats and coastal structures. Their colonial nesting habit and concentrations at sea in regions of aggregated prey increases their vulnerability to oil spills and other localized events.

Dispersal and Migration

Post-breeding dispersal by Cassin's Auklets is poorly described. There seems to be a southward migration of northern nesting birds and a northward movement by some birds from southern colonies, but auklets from central California remain in that area through the non-breeding season (Ainley *et al*. 2011). Migration routes from northern breeding colonies are inferred from distributions of the birds on the ocean during the non-breeding season. The number of birds present in waters off the California coast during fall exceeded the number known to nest in the area and it was suggested that many of these birds were migrants from British Columbia and Alaska (Briggs *et al.* 1987). The relatively low numbers of Cassin's Auklets recorded in British Columbian waters during winter provides support for that scenario. Adams (2008) also suggested that birds from Washington may migrate to California waters. However, some birds stay in Alaskan waters during the winter (USFWS 2006; McKibbin 2013a).

An increase in abundance of Cassin's Auklets off the coast of Oregon has been observed in late summer (Ainley *et al.* 2005). This increase may represent northward post-breeding dispersal by birds from California (Ainley *et al.* 2005) or may be birds from more northerly colonies moving southward. Cassin's Auklets nesting at the Channel Islands in southern California were radio-tracked to waters off central California, a distance of about 600 km (Adams *et al*. 2004).

Interspecific Interactions

Predation on Cassin's Auklets by introduced mammals at nesting colonies in British Columbia is well documented (see **THREATS AND LIMITING FACTORS**). Native mammalian predators include Northern River Otter, which excavate a small number of burrows each year at some colonies (A. Harfenist, *pers. obs.*) and may be responsible for the extirpation of a colony on Seabird Rocks (Carter *et al.* 2012), and Keen's Mice, which depredate neglected eggs on Triangle Island (Ronconi and Hipfner 2009).

Avian predators in British Columbia include Peregrine Falcon (*Falco peregrinus*), Bald Eagle (*Haliaeetus leucocephalus*), gulls (*Larus* spp.), Common Raven (*Corvus corax*) and Northwestern Crow (*Corvus caurinus*; Ainley *et al*. 2011). On Haida Gwaii, the predominant avian predators are Bald Eagles and Peregrine Falcons (Vermeer and Lemon 1986; A. Harfenist, *pers. obs*.) and Cassin's Auklets appear to be the main prey of Peregrine Falcons on Triangle Island (M. Hipfner, *pers. comm.)*. There are no indications that avian predators kill large numbers of Cassin's Auklets on Frederick Island (A. Harfenist, *pers. obs*.).

Little is known about predation on Cassin's Auklets at sea. Avian predators hunt auklets over the ocean near colonies (A. Harfenist, *pers. obs.;* M. Hipfner, *pers. comm.)*. Two birds ingested by a Humpback Whale (*Megaptera novaeangliae*) in Alaska likely represent accidental predation (Dolphin and McSweeney 1983).

Cassin's Auklet nestlings are host to the common seabird tick *Ixodes uriae* on Triangle Island (Morbey 1996); the ticks likely infest the birds at most colonies in British Columbia (M. Lemon, *pers. comm*.; A. Harfenist, *pers. obs.*). On Triangle Island, chicks with severe tick infestations had slower rates of wing growth and fledged at older ages than nestlings with fewer ticks (Morbey 1996).

Competition with other alcids for nest sites occurs at colonies in British Columbia. Rhinoceros Auklets (*Cerorhinca monocerata*) may take over Cassin's Auklet burrows (Rodway and Lemon 2011) and Cassin's Auklets and Ancient Murrelets are known to usurp each other's burrows (A. Harfenist, *unpubl. data*).

Competition with other planktivorous species for prey has not been documented; Cassin's Auklets are not usually found with other species at sea (Ainley *et al.* 2011). Ainley and Hyrenbach (2010) suggested that competition with foraging baleen whales may have contributed to the Cassin's Auklet population decline observed in the California Current System.

POPULATION SIZES AND TRENDS

Populations of many seabird species include non-breeding mature birds at the colony, as well as breeding birds (e.g., Manuwal 1974). The number of non-breeding mature Cassin's Auklets in British Columbia is unknown. Thus, in this report, the Cassin's Auklet population is considered equivalent to the number of mature breeding birds and should be considered minimum values because non-breeding mature birds have not been incorporated into estimates. The number of mature individuals in Canada is difficult to measure because the life history of Cassin's Auklet includes both terrestrial (nesting) and marine components. The species exhibits delayed maturation, and sub-adults that hatch in Canada and later return to Canada to breed may spend all or part of the intervening years in U.S. waters. In any case, the global population of Cassin's Auklets is estimated as at least 3.57 million individuals (Ainley *et al.* 2011). Estimates of the number of breeding birds are available for most colonies, although many of the counts are several decades out of date. According to a recent review (Ainley *et al*. 2011), regional percentages of the global total are estimated at: British Columbia (75.9%), Alaska (16.8%), California (3.7%), Washington (2.5%), Baja California (1.1%) and Oregon (< 0.01%). The Baja birds and approximately 20% of the California total are likely a different subspecies than the rest of the population (see **Population Structure and Variability**).

Sampling Effort and Methods

Extensive surveys along the British Columbia coast were conducted during the 1980s to develop baseline estimates for seabird colonies. Detailed descriptions of the methodologies are provided in Rodway *et al.* (1988, 1990a, b, 1994) and Rodway and Lemon (1990, 1991a, b). Total or partial counts of burrow entrances were conducted on small colonies. On larger colonies (> 1,000 pairs), burrow density was estimated using a systematic sampling scheme of line transects, with quadrats set at intervals along the line. Colony areas were measured and burrow occupancy was determined by excavating a subset of burrows. The number of breeding pairs was estimated as the product of density, area and occupancy rate. For colonies at which occupancy was not determined, the median occupancy rate (75%) was used. Surveys were conducted between April and June to overlap with the nesting season.

The main biases associated with the survey methods outlined above involve timing of the surveys and estimates of occupancy. Surveys may miss early nesters that have failed or late breeders that have not yet initiated nesting and, thus, underestimate population size. Use of the median British Columbian occupancy rate fails to incorporate variable occupancy rates into the estimates for each colony, which may lead to either over- or underestimates.

The inventory program of the 1980s surveyed 390 islands or island groups that were deemed potential seabird nesting habitat (Rodway *et al.* 1988, 1990a, b, 1994; Rodway and Lemon 1990, 1991a, b). In total, 55 Cassin's Auklet colonies were recorded. Estimates from earlier explorations by the British Columbia Provincial Museum of an additional 67 sites were also accepted; Cassin's Auklets had been reported at 7 of those sites. The Museum estimates of colony size were developed without systematic sampling and are probably accurate only within an order of magnitude. One additional colony, at Glide Islands, has been located since the 1980s, but no estimate is available for that site.

The majority of Cassin's Auklet colonies in Canada have been surveyed only once. Rigorous censuses have been repeated on nine islands, all of which are in Haida Gwaii: Charles, East Copper, Frederick, George, Gordon, Helgesen, Lihou, Ramsay, and West Rankine islands.

During the baseline surveys, permanent plots were established for trend monitoring. The monitoring plan called for plots at sites in all regions of the coast with colonies that supported at least 80% of the Canadian population (Rodway and Lemon 2011). To date, plots have been established and monitored at four colonies in two of four regions: Ramsay, East Copper and Rankine islands in Hecate Strait along eastern Haida Gwaii, and Triangle Island off western Vancouver Island. No plots have been established on islands along the northern mainland coast or the open ocean coast of Haida Gwaii. Sample plots were subjectively placed in high-density nesting areas. The area incorporated into permanent plots is equivalent to between 0.2% (at Triangle Island) and 0.9% (at Ramsay Island) of the total colony area.

Permanent plots have been resurveyed three times on East Copper and Rankine islands, four times on Triangle and five times on Ramsay (Rodway and Lemon 2011; Drever 2012). Trends calculated from systematic surveys and permanent plots have been compared for two colonies and results were similar (Rodway and Lemon 2011).

Burrow occupancy rates have been used as a measure of year-to-year fluctuations in breeding numbers at Triangle and Frederick islands (Bertram *et al.* 2005; Morrison *et al*. 2011).

Compilers of seabird colony catalogues have noted that small colonies may go unrecorded due to the difficulty in surveying nesting areas and the birds' nocturnal habit at the colony (e.g., Speich and Wahl 1989; Carter *et al*. 1992).

Data from ship-based surveys of pelagic seabirds and large-scale volunteer-based surveys along the coast have not been used to estimate Cassin's Auklet population size or trends in British Columbia. At-sea surveys specifically targeting Cassin's Auklet would be prohibitively expensive and have not been conducted. Likewise, areas surveyed during Christmas Bird Counts and Coastal Waterbird Surveys do not overlap extensively with Cassin's Auklet's offshore habitats, and numbers counted from shorelines tend to be low and variable (http://www.naturecounts.ca). Hence, results from these two surveys are also not useful for assessing population trend of Cassin's Auklet.

Abundance

Based on the most recent surveys at each colony, the Canadian breeding population of Cassin's Auklet is about 2.69 million individuals (CWS 2012 with updates from M. Lemon, *pers. comm*.). Estimates of the size of each colony are presented in Appendix 1. The above population estimate is based on surveys conducted between 1977 and 2011. Population estimates derived from surveys conducted prior to the 1980s are likely outdated and so are highly uncertain. The Canadian population is still likely somewhere between 1-3 million individuals.

Fluctuations and Trends

Canada

The breeding population of Cassin's Auklet in Canada has almost certainly declined over the past 75 years stemming from the introduction of mammalian predators to colony islands. Although historical levels are unknown, evidence of nesting is available from early explorations and the presence of abandoned nest burrows. Since the mid-1980s, when population baselines were established, the number of Cassin's Auklets breeding in the California Current System has declined, while the population in the Alaska Current System has probably remained relatively stable. Members of the Hesquiaht, Ahousaht and Tla-o-qui-aht Nations on Vancouver Island have also identified a decline in Cassin's Auklet numbers and attributed it to climate change (Lerner 2011).

On Triangle Island (the world's largest Cassin's Auklet colony), the number of burrows in permanent monitoring plots declined by 2.5% per year from 1989-2009 (Rodway and Lemon 2011). The result has been an apparent 40% decline in burrows over 20 years, or approximately three generations. Burrow numbers within transect plots on neighbouring Sartine Island declined by 48% between 1987 and 2006 (Hipfner *et al.* 2010). As occupancy rates were not actually determined at either site, extrapolations from numbers of burrows to numbers of nesting birds is speculative. However, if burrow counts at Triangle and Sartine islands are directly translated to a trend in the nesting population, then the declines represent a loss of about 799,000 breeding birds at these sites since the late 1980s.

Although annual population censuses are not conducted at any site in Canada, burrow occupancy can be used as an index of year-to-year fluctuations in numbers at a single colony. Over a 15-year period from 1994-2008, burrow occupancy fell at Triangle Island in 1998 and in 2006-2007 (Bertram *et al*. 2005; Hipfner *et al.* 2010b; Morrison *et al.* 2011). Low occupancy rates have been related to strong El Niño events. Together with the demographic information presented previously, the burrow occupancy data suggest that the negative trend in Cassin's Auklet on Triangle Island has been characterized by periodic steep declines during extreme climate events when female survival is less than 50%, reproductive output is reduced and burrow occupancy is low; the intervals between these events allow the population to slowly build up again (M. Hipfner, *pers. comm*.). Similar cycles have been described for the Farallon Islands population (Warzybok and Bradley 2011). Shorter intervals between extreme events, as are predicted with global climate change, will allow less time for the population to recover. In addition, the loss of high-quality nesting habitat, while not believed to be causing the population decline at Triangle Island, will likely inhibit recovery (Hipfner *et al.* 2010a).

The oceanographic changes that are driving the decline in Cassin's Auklet numbers at Triangle Island are occurring throughout the California Current System, and population declines have been described at the Farallon Islands (see following section on trends in the United States). Similarities in the impacts of ocean conditions on Cassin's Auklet survival, reproductive success and numbers across a broad geographic scale suggest that other Canadian colonies within this system are also being negatively affected.

Inter-annual fluctuations in population numbers related to extreme climate events occur in the Alaska Current System as well: burrow occupancy fell at Frederick Island during the 1998 El Niño (Bertram *et al.* 2005) and burrow densities were low in 1998 and 2005 (M. Lemon, *pers. comm*.). However, permanent plot monitoring results from three islands in southeastern Haida Gwaii suggest that their populations are relatively stable. Burrow counts on Ramsay Island increased at 1% per year between 1984 and 2012, whereas those on Rankine Island declined at an annual rate of 1.4%. (Drever 2012). Burrow counts on East Copper Islands declined by about 16% from 1985 to 2009 (Rodway and Lemon 2011). Anecdotal evidence suggests that the small colony on East Limestone Island may have increased over the past 5 years (A. Brown, *pers. comm.*), along with the population at nearby Reef Island since the 1990s (A.J. Gaston, pers. comm.). The results of a resurvey of Frederick Island in 2005, which are not yet fully analysed, may indicate a population decline at that location: burrow density and occupancy were lower than in 1980, but colony area in 2005 has not yet been calculated (Moira Lemon, *pers. comm*.).

Although the Canadian population of Cassin's Auklet appears to fluctuate, the fluctuations are not "extreme fluctuations" as defined by the IUCN (2011): changes in the total number of mature individuals that occur rapidly and frequently, typically with a variation greater than one order of magnitude (i.e., a tenfold increase or decrease). Burrow occupancy on Triangle and Frederick islands fell by 20-30% following the 1997/1998 El Niño (Bertram *et al.* 2005); on Triangle Island, burrow occupancy fell by approximately 40% following the 2005 atmospheric anomaly (Hipfner *et al*. 2010b). These limited data span a 15-year period, or approximately 2 generations.

Populations on islands colonized by non-native predators have almost certainly declined. For example, a colony of about 7,400 birds on Helgesen Island, in southwestern Haida Gwaii, declined by 95% between 1986 and 1993, owing to raccoon depredation (Gaston and Masselink 1997). Similarly, introduced raccoons and mink destroyed colonies of unknown size on Lanz and Cox islands, southeast of Triangle Island prior to 1989 (Rodway *et al.* 1990b). A small colony of approximately 320 birds on Seabird Rocks, off southwestern Vancouver Island, was destroyed between 2003 and 2011; the most likely cause was predation by River Otter (Carter *et al.* 2012).

A population viability analysis (PVA) has not been conducted for British Columbia. Nur *et al.* (2011b) developed a PVA for the Farallon Islands population of Cassin's Auklets and the results are discussed briefly below. Although the specifics of the model output cannot be extrapolated to Canadian colonies in the California Current System because key demographic parameters differ between the two areas, some of the general conclusions are relevant. The PVA projects a declining population if recent fluctuations in ocean conditions persist over the next two decades.

In summary, a 40% decline in burrow numbers at Triangle Island from 1989 to 2009 could be used to extrapolate to other colonies within the California Current System, which represents about 75% of the Canadian population. As such, a population decline of about 30% could be inferred over the last three generations, assuming that the remainder of the Canadian population has been stable. These assumptions are, however, untested and based on rather scanty data, so need to be verified. As such, while it appears clear that declines have indeed taken place, a rate of decline cannot be reliably calculated at this time.

United States and Mexico

As is the case for the Canadian Cassin's Auklet population, evidence from early explorations and abandoned burrows indicates that populations in the United States and Mexico declined from historical levels due to the introduction of mammalian predators, but the magnitude of the loss is not known. Alaska's population was probably larger than that of British Columbia (Ainley *et al*. 2011). Numbers on the Aleutian Islands and Gulf of Alaska were greatly reduced by fox predation (Springer *et al*. 1993). Extirpations and declines on islands in southern California and Baja California due to introduced predators have also been reported (e.g., Wolf *et al*. 2006). The trend has been reversed on the southern colonies with the removal of non-native species (Whitworth *et al.* 2012; M. Félix-Lizárraga, *pers. comm.*). Recovery in Alaska is likely as well: the eradication of foxes from former colony sites was followed by recolonizations by many species of seabird (Byrd *et al.* 2005). However, there are no population trend data for Cassin's Auklet in Alaska (Byrd *et al*. 2005).

Declines have been reported from Oregon and northern California. Oregon breeding population estimates fell from 220 birds at 3 sites (with probable nesting at an additional 5 sites) in 1979 to 70 birds in 1988 and 20 birds at a single site in 2008 (Naughton *et al*. 2007; Kocourek *et al*. 2009). However, some of the observed decline may reflect differences in census techniques used in different years; the latest survey used methods known to underestimate burrow-nesting birds (Kocourek *et al*. 2009). At Castle Rock in northern California, numbers dropped from 5638 to 86 birds between 1989 and 2007 (Carter *et al.* 1992; Cunha 2010).

The best trend data are from the Farallon Islands in California, where numbers of nesting birds have declined by more than 85% since 1971 (Lee *et al.* 2007). The rate of decline was estimated at about 2.4% per year since 1991 (Warzybok and Bradley 2011). Underlying the trend are fluctuations between periods of population growth and decline (Warzybok and Bradley 2011). The population decline has been attributed to declines in zooplankton biomass and changes in prey availability (e.g., Ainley *et al*. 1996; Sydeman *et al*. 2001). Wolf *et al.* (2010) projected that population growth rate would entail an absolute decline of 11-45% by the end of the century and eventual extinction.

Farallon Islands data have been used to conduct a PVA for that population (Nur *et al*. 2011b). In contrast to the model developed by Wolf *et al* (2010), the PVA incorporated stochasticity in key demographic parameters. The PVA output showed a population decline of 27% over the next 20 years if El Niño frequency remains at the same level as over the last 30 years (Nur *et al*. 2011b). If the frequency of El Niños remains stable and an anomalous atmospheric blocking event reoccurs, then the decline is projected to be more than 62% over 20 years. The PVA suggested that the population could remain stable if predation on adults was reduced; a minimum predation rate of 1-2% of breeding birds was recorded on the island.

Rescue Effect

Cassin's Auklets south of British Columbia are likely undergoing declines similar to those at Canadian colonies within the California Current System. Thus, there is no expectation that dispersal from Washington, Oregon or California will repopulate the Canadian population. Furthermore, auklets breeding in southern California and Baja likely represent a different subspecies (Wallace *et al.* in press). Trends from Alaska are undetermined, but it is reasonable to assume that Cassin's Auklets there have recovered to an unknown degree from historical declines.

The greatest inhibitor to rescue from Alaska is likely to be the species' strongly developed natal philopatry and nest site fidelity. Nevertheless, Cassin's Auklets have become re-established on islands from which they had been eliminated (see **Introduced Species**).

Local extirpations of Cassin's Auklet colonies in the California Current System are most likely to occur as a result of ocean warming, possibly in conjunction with vegetation change and depredation by mammals. Local extirpations of colonies in the Alaska Current System are most likely to occur as a result of the introduction of mammalian predators. Reversal of ocean warming is unlikely in the foreseeable future, inhibiting rescue. Furthermore, the broad geographic area over which impacts are projected to occur will limit the availability of potential source populations.

THREATS AND LIMITING FACTORS

Cassin's Auklets face a range of threats in both their terrestrial and marine habitats that vary in scale from localized to ocean-wide (e.g., Ainley *et al*. 2011; BC Ministry of Environment 2004). The concentration of Cassin's Auklets at colonies during the nesting season and over aggregated prey on the ocean renders the birds vulnerable to certain threats (e.g., introduced predators and oil spills). However, their large population and wide geographic range increases their resilience against extirpation in Canada.

The significance of threats to the British Columbia population of Cassin's Auklet was assessed using the COSEWIC Threats Assessment Worksheet. An overall threat impact of "very high" to "medium" was calculated from the results (Appendix 2).

Hydrocarbon Pollution and other Contaminants

Lethal and sublethal effects of oil on seabirds have been extensively reviewed (e.g., Burger and Fry 1993; Camphuysen 2007) and the pathology of Cassin's Auklets exposed to oil has been described (Fry and Lowenstine 1985). Alcids are considered highly vulnerable to oil pollution because they spend much of their time on the water, nest colonially, forage by pursuit diving and tend to aggregate at sea (e.g., Camphuysen 2007). However, unlike many other alcids, Cassin's Auklets do not gather on the waters immediately around their colonies, which may reduce their vulnerability to oil contamination (USFWS 2006). Nevertheless, as noted by Bertazzon *et al.* (2014), a single catastrophic spill off the coast of Triangle Island could put over 50% of the global population of Cassin's Auklets at risk.

Mortality from oil spills has been recorded in British Columbia and elsewhere. About 32% of the documented seabird mortality following the 1988 *Nestucca* oil spill were Cassin's Auklets (Burger 1992). Mortality was also recorded following the *Apex Houston* spill in California (Page *et al.* 1990). Although large catastrophic oil spills receive most of the attention, more frequent but smaller-scale discharges of oily wastes (often referred to as "chronic") may contribute more oil to marine waters (National Research Council 2003; Camphuysen 2007). A predicted increase in tanker and cruise ship traffic along the coast of British Columbia is expected to result in an increase in chronic oiling in the area (Johannessen *et al.* 2007). Of particular concern are the proposed shipping of diluted bitumen (the Northern Gateway project) and liquefied natural gas (several projects) from ports in northern British Columbia: these would increase tanker traffic through and near major concentrations of nesting and foraging Cassin's Auklets (National Energy Board and

Canadian Environmental Assessment Agency 2013), and, thus, increase the risks of oil contamination to this species. The proposed doubling of the Trans-Mountain oil pipeline to the south coast would increase tanker traffic through marine waters used by Cassin's Auklets off southwestern Vancouver Island (National Energy Board 2013).

Despite the above, increased surveillance of oil discharges in British Columbia's marine waters, conducted under the National Aerial Surveillance Program (NASP), may result in a reduction of chronic oil contamination in at least a portion of the marine waters used by Cassin's Auklet. The proportion of oiled bird carcasses and beaches found during Beached Bird Surveys on the west coast of Vancouver Island has declined since the onset of the NASP in the early 1990s, which provides support for a deterrence effect of surveillance (O'Hara *et al.* 2009). O'Hara *et al.* (2013) reported evidence of reduced oily discharge rates with increased surveillance in the Strait of Georgia, where surveillance effort was high, but only limited or no evidence of a similar relationship off the west coast of Vancouver Island and north of Vancouver Island where surveillance effort was lower. The latter study was conducted using data through 2006. NASP surveillance effort has increased along the coast since that time, but the impacts of that increase on oily discharges over much of the range of Cassin's Auklets (see Figures 4 and 5) are not yet known.

The levels of organochlorines and heavy metal contaminants reported for Cassin's Auklets in British Columbia are low and not expected to cause serious population effects (Elliot and Noble 1993; Elliott and Scheuhammer 1997). Organochlorine pesticide contamination in Cassin's Auklets from Haida Gwaii was generally lower than that in most other seabird species examined (Elliott *et al.* 1997). Hipfner *et al.* (2011) found little variation in mercury load over the course of the breeding season or between years at Triangle Island.

Ocean Warming/Climate Change

Researchers have argued that the Cassin's Auklet's sensitivity to natural cycles in ocean climate indicates that the species is vulnerable to climate change (e.g., Wolf *et al.* 2010; Nur *et al.* 2011b). Sydeman *et al*. (2009) suggested that anthropogenic climate change has caused much of the observed declines in the birds' productivity over the last decades, although some of the variability reflects natural cycles such as El Niño events and the Pacific Decadal Oscillation.

Effects of climate change on ocean ecosystems have been reviewed (e.g., IPCC 2007; Doney *et al.* 2012). Predicted consequences include increased ocean temperature, increased variability in oceanographic conditions including frequency or amplitude of El Niños, increased ocean acidification, increased frequency and intensity of storms, and higher rainfall in some areas (e.g., Meehan *et al.* 1999; Guilyardi 2006; IPCC 2007). Probable negative impacts of warming ocean waters and increased frequency of El Niños on Cassin's Auklet have been assessed based on comparisons of reproductive parameters and survival between warm and cold water years (see **BIOLOGY**). Links between the warm water phases of natural cycles and depressed productivity and survival in Cassin's Auklet in the California Current System and, to a lesser extent, in the Alaska Current System, are well established (e.g., Bertram *et al*. 2005; Hipfner 2008; Morrison *et al*. 2011; Nur *et al*. 2011b). Increased frequency of such events and background warming of the ocean are expected to result in increasingly frequent mismatches between the birds and their prey. The birds on Triangle Island do not seem to have a high-quality alternative food source when their main prey becomes unavailable (Hipfner 2009). Increasing acidification of the ocean is expected to negatively impact organisms containing calcium carbonate including some phytoplankton and zooplankton (DFO 2012). Impacts at lower trophic levels are, in turn, expected to impact the prey base of Cassin's Auklets. Increased frequency and intensity of storms could negatively impact winter survival of the birds (Meehan *et al.*1999) and reduce breeding habitat suitability due to tree blowdowns and subsequent spruce regeneration. Higher rainfall amounts could affect the ability of burrows to provide adequate protection for nestlings (Meehan *et al.*1999).

Climate change may result in large-scale redistributions of seabirds. Thompson *et al.* (2012) demonstrated an increase in Cassin's Auklets in the Alaska Gyre across all seasons and suggested that the poleward shift in isotherms and seasonal changes in temperature may be improving marine habitat quality for the birds in that region by lengthening the season of prey availability.

Given the broad-scale of the threat, and evidence of links between warm ocean waters and declines in Cassin's Auklet populations at two widely separated sites in the California Current System, all Canadian colonies in that System (about 75% of the total Canadian population) could be at risk from anthropogenic climate change. In contrast, impacts on birds nesting in the Alaska Current System are likely to be less severe, at least over the short- to medium-term.

Introduced Species

Non-native species, including introduced rats, raccoons and mink, continue to pose a serious threat to Cassin's Auklets at breeding colonies in British Columbia (Bailey and Kaiser 1993; Harfenist *et al.* 2002). Black and Norway rats (*Rattus rattus* and *R. norvegicus,* respectively) have impacted Cassin's Auklets at five islands, all in Haida Gwaii, leading to extirpation of three colonies and possible decline at the others (Table 3). Rats prey on adults, nestlings and eggs. There is a risk of rats spreading to additional colony islands by swimming from rat-infested islands, although the short dispersal distances possible for rats in cold marine waters (no more than about 300 m; Taylor 1984) limits the number of colonies threatened. However, rats can reach new colonies on commercial and recreational boats or ship wrecks. Activities associated with the numerous fishing lodges at Langara Island are a potential route for reintroduction of rats to that colony.

Table 3. Cassin's Auklet colonies in British Columbia reached by introduced predators (Rodway *et al.* 1990b; Gaston and Masselink 1997; Harfenist *et al.* 2002).

Island/Islet	Introduced Species	Impact
Langara	Rat	Extirpated
Cox	Rat	Extirpated
Helgesen	Raccoon	95% decline 1986-1993
Saunders	Raccoon	Extirpated
St. James	Rat	Extirpated
Kunghit	Rat, raccoon	Decline suspected
Rock 1	Raccoon	Based on sighting in 1992
Skincuttle 1	Raccoon	Based on sighting in 1992
George 1	Raccoon	Based on sighting in 1992
Alder	Raccoon	
Ramsay	Raccoon	
Murchison	Rat	Decline suspected
East Limestone	Raccoon	
Skedans	Raccoon	
Lanz	Mink	Extirpated
Cox	Mink, raccoon	Extirpated

[1] Evidence from these islands is questionable.

Raccoons have been found on at least 9, and possibly 11, colony islands; they have eliminated or reduced populations of Cassin's Auklets nesting on most of those islands (e.g., Gaston and Masselink 2007). They excavate auklet burrows and eat adults, chicks and eggs. Raccoons swim easily between islands, presenting a constant risk. The British Columbia Conservation Data Centre (2012) considers raccoon predation a threat to 80% of the Canadian Cassin's Auklet colonies, representing 20% of the population.

Mink and raccoons were introduced to Lanz and Cox islands and likely eliminated Cassin's Auklet populations of unknown size on those islands by the late 1980s (Bailey and Kaiser 1993). Mink depredation of birds attempting to nest on Lanz Island has continued over the past two decades (Rodway *et al.* 1990b; Hipfner *et al*. 2010a).

Rats have been eradicated from Langara and St. James islands in Haida Gwaii (Kaiser *et al.* 1997; Golumbia 2000) and a small colony of Cassin's Auklets has re-established itself on Langara (Regehr *et al*. 2007). Raccoons have been removed from Helgesen, Saunders and East Limestone islands, but the proximity of those islands to source areas means that recolonization is likely (e.g., Brown 2010; Gaston *et al*. 2011).

At Helgesen and Saunders islands, federal and provincial government agencies developed monitoring and management plans with the participation of the Council of the Haida Nation and a local conservation society (Harfenist *et al*. 2000). The plans involved annual monitoring of colonies for raccoon presence and killing any raccoons found. Parks Canada and the Laskeek Bay Conservation Society continue annual monitoring (D. Argument, *pers. comm.*, Brown 2010), but the Canadian Wildlife Service monitors at a much reduced frequency (L. Wilson, *pers. comm*.) and BC Parks has not monitored for raccoons over the last decade (L. Stefanyuk, *pers. comm*.).

Elsewhere in their range, Cassin's Auklet numbers have been impacted by introduced Red and Arctic foxes (*Vulpes vulpes* and *Alopex lagopus;* Alaska), rats (Alaska, California, Baja California) and cats (*Felis catus*; California, Baja California; e.g., Bailey and Kaiser 1993; Wolf *et al.* 2006). Extensive eradication efforts have been conducted in Alaska, California and Baja California, and Cassin's Auklets thereafter returned to at least some of their former colonies (Aguirre-Muñoze *et al*. *2011;* Whitworth *et al*. 2012; M. Félix Lizárraga, *pers. comm*.; B. Keitt, *pers. comm.).*

Alaska has developed a response protocol to deal with potential future threats of rat introductions to seabird colony islands following shipwrecks (Ebbert *et al.* 2007). There is no similar plan for Canada. However, Parks Canada has produced a pamphlet outlining measures that recreational boaters can take to avoid transporting rats to islands in Haida Gwaii.

Herbivores have also been introduced to some Cassin's Auklet colonies. European Rabbits (*Oryctolagus cuniculus)* were released on Triangle Island, and Sitka Black-tailed Deer (*Odocoileus hemionus sitkensis*) are now found on most islands in Haida Gwaii. Impacts on Cassin's Auklet have not been documented for either species. However, in southern California and Baja California, introduced herbivores are considered a threat to Cassin's Auklets, because of the habitat damage done by trampling, as well as increased soil fragility due to vegetation loss or change (McChesney and Tershy 1998; Aguirre-Mu*ñoze et al. 2011)*.

Finally, non-native vegetation that displaces native flora has also been identified as a threat in southern California, because it increases soil salinity and erosion rates (Adams 2008). On the other hand, non-native plants can stabilize soil in some sites (M. Hester, *pers. comm., cited in* Adams 2008).

Vegetation Change

Significant changes to plant communities have been described at a number of Cassin's Auklet colonies in British Columbia. Shifts in the plant communities may be linked to drier and warmer local climate conditions (Hipfner *et al.* 2010a). Triangle and Sartine islands have experienced extensive declines in high-quality Tufted Hairgrass habitat and a concurrent increase in less suitable Salmonberry cover (Hipfner *et al*. 2010a). Although the observed alterations are not believed to be driving the decline in numbers of nesting Cassin's Auklets at those sites, a decrease in suitable habitat may inhibit recovery of the species (Hipfner *et al.* 2010a).

Windfall and dense regeneration of Sitka Spruce resulting in a loss of nesting habitat for Cassin's Auklet have been described at two islands in southeast Haida Gwaii (Rodway and Lemon 2011). An increase in wind storms, as predicted under climate-change scenarios (see above), is likely to exacerbate the threat of uprooted trees and spruce regeneration.

Shipping

The passage of ships through marine waters used by Cassin's Auklets is associated with unquantified levels of disturbance and risks of mortality or injury from collisions. Cassin's Auklets may be displaced from their feeding areas by boat traffic, but the distance at which adults or young leave an area when vessels pass by and the duration of displacement are unknown. Artificial lights may disorient Cassin's Auklets, causing them to fly into structures (see **Human Activity)** and, thus, lights on boats are likely to increase the probability of collisions. As noted above (see **Hydrocarbon Pollution and other Contaminants**), boat traffic is projected to increase in coastal BC. The impacts of increased shipping will depend on the overlap between the shipping routes and Cassin's Auklet foraging habitats.

Fisheries Interactions

Cassin's Auklets may interact with fisheries through bycatch in the gillnet fishery and direct competition for prey. Whereas the former has been documented, the latter is speculative.

Smith and Morgan (2005) extrapolated from bycatch data to estimate that the annual bycatch by the entire gillnet fishery fleet was only 31 Cassin's Auklets (minimum of 3, maximum of 62) in 1995-2001. The estimated capture frequency was relatively low compared to that of many other species of seabirds. Small numbers of Cassin's Auklets were also caught in an experimental squid fishery off British Columbia in the 1970s and 1980s (DeGange *et al.* 1993). Bycatch in Canadian fisheries is not considered to be a serious threat at this time.

Euphausiids and rockfish, two prey of Cassin's Auklets, are fished in British Columbia. *Euphausia pacifica* have been commercially fished since the 1970s in inlets in the Strait of Georgia to supply aquaria and salmon farms (DFO 2013). As euphausiid fishing is banned in offshore waters, there is minimal spatial overlap between the fishery and Cassin's Auklet foraging. Thus, at present, the euphausiid fishery is unlikely to present a major threat to the birds' food base. Commercial and recreational fishing of rockfish may affect the availability of larval stages to the birds (Vermeer *et al*. 1997), but no estimate of impact is available.

Human Activity

Human activity can damage Cassin's Auklet nesting habitat and harm the birds (e.g., Ainley *et al*. 2011). The threats are primarily associated with recreational activities, but may also arise as a result of research or commercial activities. Walking on nesting areas can cause burrows to collapse, and exposed nests may be depredated or abandoned by adults. In forested habitats, the nest chamber is frequently the weakest part of the burrow and, thus, the most likely to collapse (A. Harfenist, *pers. obs*.). Damage by commercial and recreational fishers, as well as kayakers, walking through the colonies has been observed in Haida Gwaii (A. Harfenist, *pers. obs*.). Because the birds are not active at the colony during the day, visitors may be oblivious to their presence and the damage caused. Research projects that involve handling adults or chicks can result in mortality or reduced chick growth (A. Harfenist, *pers. obs*.). In addition, activities that alter the shoreline during the nesting season, such as log-salvage operations, may destroy nests of the small percentage of Cassin's Auklets that nest in piles of driftwood.

Artificial lights, including boat anchorage and cabin lights, lanterns, bonfires and lights associated with fishing lodges, can attract and disorient birds, causing collisions with structures or ropes and resulting in injury and death. Historical hunting methods involved setting bonfires on the shoreline for the birds to fly into (Heath 1915). Artificial lights near the colony may also lead to increased predation rates on Cassin's Auklets by avian species (Adams 2008).

Due to the isolation of many of British Columbia's colonies, damage from human activity is probably quite localized and of low intensity. The most accessible colony, Cleland Island, is within an Ecological Reserve with a prohibition on visitors that seems well patrolled by local tour guide operators (A. Harfenist, *pers. obs*.).

Offshore Development

Offshore oil and gas development and wind turbines may pose a risk to Cassin's Auklets in the future. Oil and gas exploration and extraction are associated with an elevated risk of oil spills and light hazards. The degree of risk from wind turbines is unknown.

Number of Locations

Colonies are considered separate locations (IUCN 2011) because some of the threats faced by the birds, including the serious threat from introduced predators, are colony-specific. Hence, the number of locations (62) is equal to the number of colonies.

PROTECTION, STATUS AND RANKS

Legal Protection and Status

Cassin's Auklets are protected in Canada by federal and provincial legislation. The *Migratory Birds Convention Act* protects the birds, their nests and eggs from hunting and collecting. The *Canada National Parks Act* protects breeding colonies within National Parks. At the provincial level, the birds (except those on federal lands) are protected under the *Wildlife Act;* Wildlife Management Areas have been established to protect breeding colonies under this Act. Nesting habitat is protected in Ecological Reserves established under the *Ecological Reserves Act*. Cassin's Auklet is an "Identified Species," and breeding colonies were designated as Wildlife Habitat Areas under the Identified Wildlife Management Strategy in the *Forest Range and Practices Act.* Wildlife Habitat Areas established to protect colonies under that Act have been dissolved and the colonies are now formally protected by British Columbia and the Haida Nation under *The Protected Areas of British Columbia (Conservancies and Parks) Amendment Act (2008 and 2009).* Wildlife Habitat Areas are mentioned here because references to them still appear in documents and on websites. The types of protection for Cassin's Auklet nesting colonies in British Columbia are summarized in Table 4.

Table 4. Types of protection for Cassin's Auklet nesting sites in British Columbia (expanded from Harfenist *et al.* 2002).

Type of Area Protection [1]	Number of Islands/ Island Groups [2]	Locations
National Park/National Park Reserve	24	All islands within Gwaii Haanas National Park Reserve/Haida Heritage Site; Seabird Rocks
Ecological Reserve	19	Lepas, Hippa, Cleland, Triangle, Solander, Sartine, Beresford, Glide, Moore, McKenney, Byers, Conroy, Sinnett, Harvey, Herbet, Bright, Storm, Reid, Tree
Haida Gwaii Heritage Site/Conservancy	24	All colonies in Haida Gwaii outside Gwaii Haanas
Provincial Park	2	Lanz, Cox

Type of Area Protection [1]	Number of Islands/ Island Groups [2]	Locations
Wildlife Management Area [3]	3	Reef, Limestone, Skedans
None	1	Egg

[1] Until recently, 19 colonies in Haida Gwaii were designated as Wildlife Habitat Areas. This designation no longer applies because the colonies are within Duu Guusd, Daawuuxusda and K'uuna Gwaay Haida Heritage Sites/Conservancies.

[2] The total does not equal the total number of colonies in British Columbia because of overlapping designations.

[3] This designation will eventually be obsolete because islands are within Kunxalas and K'uuna Gwaay Heritage Sites/Conservancies.

At sea, Cassin's Auklets are protected by the *Canada National Marine Conservation Areas Act* (within National Marine Conservation Areas) and the *Oceans Act* (within Marine Protected Areas). Protection within the proposed Scott Islands Marine Protected Area would be provided by the *Canada Wildlife Act*. Regulatory authority for the issue of seabird bycatch in fisheries is shared by Environment Canada (*Migratory Birds Convention Act*) and Fisheries and Oceans Canada (*Fisheries Act, Oceans Act, Department of Fisheries and Oceans Act*).

In the United States, Cassin's Auklets are protected under the *Migratory Bird Treaty Act*. The birds are federally listed as "threatened" in Mexico (Secretaria de Medio Ambiente y Recursos Naturales 2002, *cited in* Wolf *et al*. 2006).

Non-Legal Status and Ranks

The status of Cassin's Auklet as provided by NatureServe and the BC Conservation Data Centre are listed below (S2 = imperilled; S3 = vulnerable; S4 = apparently secure).

Global Status and Rounded Global Status: G4 (1996) Apparently Secure
IUCN Red List Category: Least Concern

Canada National Status: N2N3B (2011)
BC Provincial Status: S2S3B,S4N (2005)
Provincial Conservation Status: Special Concern (Blue List)

General Status for Canada is 3 = Sensitive (2005).

United States National Status: N4
Alaska: S4
Washington: S3
Oregon: S2B
California: S2S4

Cassin's Auklet is a Bird Conservation Region 5 (Northern Pacific Rainforest) priority species (Environment Canada 2013); it is ranked as being of "Moderate Conservation Concern" in Canada's Waterbird Conservation Plan (Milko *et al.* 2003), the Canadian component of the North American Waterbird Conservation Plan (Kushlan *et al.* 2002). Cassin's Auklet is considered a species of "high" concern in the Alaska Seabird Conservation Plan (USFWS 2006) and is listed as a California Bird Species of Special Concern (breeding) (Adams 2008).

Habitat Protection and Ownership

The vast majority of Cassin's Auklet nesting colonies have some level of formal protection. In Canada, all but one active Cassin's Auklet colony (Egg Island with an estimated population of only 10 individuals) is formally protected (Table 4). Three historic colonies that no longer support active colonies are within Gwaii Haanas National Park Reserve/ Haida Heritage Site or Daawuuxusda Heritage Site/Conservancy. Two islands from which Cassin's Auklets were eradicated by raccoons or mink are within a provincial park.

The protected areas designations should prevent most development and deliberate introductions of non-native species, as well as restrict some human activities. They do not, however, prevent accidental introductions of non-native species. In addition, poor enforcement of existing rules is the norm due to the often isolated nature of the colonies. The ecological reserve on Hippa Island receives small numbers of visitors who may damage habitat and disturb birds. In contrast, at Cleland Island, which is an ecological reserve that is a focus of many boat tours, the ban on visitation is maintained by the tour operators.

In the United States, most of the breeding sites are protected within the National Wildlife Refuge or National Parks systems. In Mexico, Guadalupe Island and surrounding islets have been designated as a Biosphere Reserve (Wolf *et al.* 2006).

The marine habitat of Cassin's Auklet is less completely protected. In Canada, Gwaii Haanas National Marine Conservation Area and Bowie Seamount Marine Protected Area cover a portion of the marine waters used by Cassin's Auklets. However, it is unclear at present how much protection is conferred by these designations, as vessel traffic and fishing activities are allowed within or near the boundaries.

In the United States, National Marine Sanctuaries encompass marine waters used by Cassin's Auklets. The Guadalupe Island reserve in Mexico includes marine waters around the islands.

Recognition, but no formal protection, is provided by designation of colonies and/or nearby marine waters as Important Bird Areas (IBAs) or Biosphere Reserves. The locations of IBAs along the Pacific coast of Canada can be viewed at http://www.ibacanada.ca/mapviewer.jsp?lang=EN. The Clayoquot Biosphere Reserve includes Cleland Island and waters used by Cassin's Auklets. IBAs and Biosphere Reserves encompassing Cassin's Auklet colonies and marine habitat have also been recognized in the United States and Mexico.

Conclusions on Legal Protection and Status

The legal protection that covers virtually all of Cassin's Auklet nesting habitat in British Columbia affords only partial protection against the most notable and most preventable threat to that habitat: introduced mammalian predators. The habitat is protected against human activities to some degree, although enforcement is negligible over much of the range due to the isolation of the islands. It is not evident whether vegetation changes are more or less likely to be actively managed given the colonies' protected status.

Existing marine habitat protection was not established for seabird values (Marine Protected Areas) or does not overlap the offshore areas preferred by Cassin's Auklets (National Marine Conservation Area). Furthermore, neither designation protects against the impacts of ocean warming, which is likely the most serious threat facing the majority of Canada's Cassin's Auklets.

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Anne Harfenist is a biologist with an M.Sc. in Behavioural Ecology from Simon Fraser University and a B.Sc. in Zoology from the University of Western Ontario. She has more than 30 years of experience working on marine and freshwater birds as a self-employed consultant and Canadian Wildlife Service biologist. For the past 22 years, she has worked on Pacific seabirds including Cassin's Auklets. Her research on Cassin's Auklet includes studies of diet, reproduction and survival.

COLLECTIONS EXAMINED

There were no collections examined for this report.

Appendix 1. Estimated number of breeding individuals at known colonies in Canada. Estimates are based on latest survey conducted at a site. Data sources: Rodway *et al*. 1988, 1990a, b, 1994; Rodway and Lemon 1990, 1991a, b; Harfenist 1994; Gaston and Masselink 1997; Regehr *et al.* 2007; Carter *et al.* 2012; and M. Lemon, *pers. comm.*

Location [1]	Estimated No. of Breeding Individuals	Survey Year	Type of Survey [2]
HAIDA GWAII			
Agglomerate I.	400	1884	E – breeding suspected
Alder I.	6348 ± 1856	1985	T
Barry It.	200	1977	E
Between It.	200	1977	E – breeding suspected
Bolkus Is.	1920	1985	C – occupancy not determined [3]
Cape Kuper	240	1986	C
Carswell I.	360	1986	E – breeding suspected
Charles I.	0	1993	T
Cox I.	0	1981	T
East Copper I.	21,200	2003	T
East Limestone I.	80	1983	C – occupancy not determined
Frederick I.	179,704 ± 6338	1980	T
George I.	8600	1996	T
Gordon Is.	1040	1993	PC
Helgesen I.	400	1993	T
Hippa I.	25,080 ± 6314	1983	T
Hotspring I.	20	1986	E – breeding suspected
House I.	80	1984	E – breeding suspected
Howay I.	500	1985	E – breeding suspected
Jeffrey I.	5346 ± 4272	1985	T
Kawas Its.	400	1985	E
Kerouard Is.	155,870 ± 17,932	1986	T – occupancy not determined
Kiokathli Its.	600	1977	E
Langara I.	24	2004	C
Lepas It.	400	1977	E
Lihou I.	26,208	1993	T
Lost I.	420	1983	C – occupancy not determined
Low I.	60	1983	C – occupancy not determined
Luxmoore I.	760	1986	T – occupancy not determined

Location [1]	Estimated No. of Breeding Individuals	Survey Year	Type of Survey [2]
Marble I.	10,000	1977	E
Moresby Its.	160	1986	E
Murchison I.	100	1984	E
Ramsay I.	25,774 ± 5542	1984	T
Rankine I. (east)	7956 ± 3598	1985	T – occupancy not determined
Rankine I. (west)	27,734 ± 7490	2000	T
Reef I.	3400	1983	E
Rock It.	10,200	1985	T – occupancy not determined
Rogers I.	80	1986	E – breeding suspected
Saunders I.	0	1993	PC
S'Gaang Gwaii	49,474 ± 7680	1985	T
Skedans Is.	206	1983	C
Skincuttle I.	1860 ± 760	1985	T – occupancy not determined
Solide I.	1900	1977	E
St. James I.	0	1986	PC
Tar Is.	240	1985	E – breeding suspected
Tian Its.	200	1986	E
Titul I.	340	1983	C – occupancy not determined
Willie I.	340	1986	E – breeding suspected
NORTHERN MAINLAND COAST			
Byers I.	37,612 ± 8566	1988	T
Conroy I.	900	1988	E – breeding suspected
Egg I.	10	1988	C – breeding suspected
Glide Is.	not available		
Harvey Is.	1880	1988	E – breeding suspected
McKenney Is.	80	1988	E – breeding suspected
Moore Is.	800	1988	E – breeding suspected
Sinnett Its.	4252 ± 2424	1988	T – occupancy not determined
VANCOUVER ISLAND			
Bright Island	7398 ± 2212	1987	T – occupancy not determined
Beresford I.	132,134 ± 21,394	1987	T
Cleland I.	1610 ± 610	1988	T – occupancy not determined
Cox I.	0	1987	PC
Herbert I.	4358 ± 1702	1987	T – occupancy not determined
Lanz I.	0	1987	PC

Location [1]	Estimated No. of Breeding Individuals	Survey Year	Type of Survey [2]
Reid Its.	526 ± 364	1987	T – occupancy not determined
Sartine I.	751,804 ± 53,194	1987	T
Seabird Rocks	0	2011	C
Solander I.	67,772 ± 8642	1989	T
Storm Is.	600	1987	E – breeding suspected
Tree Its.	500	1986	E
Triangle I.	1,095,274 ± 51,496	1989	C (1989 results are used here, because that was the last time a total census was conducted)

[1] Locations include former colony islands.

[2] C = total count; PC = partial count; T = transects; E = estimated without standardized methodology.

[3] For sites at which occupancy was not determined, the median B.C. occupancy rate (75%) was used to calculate the population, with the exception of East Ramsay Island for which the occupancy rate at West Ramsay Island was used.

Appendix 2. Threat classification table for Cassin's Auklet. Assessed by Ruben Boles, Alan Burger, Dave Fraser, Anne Harfenist, Ken Morgan, Jon McCracken, Julie Perrault and Mary Sabine on June 25, 2014. Cells for threats considered not applicable are left blank.

Threat Impact		High Range	Low Range
A	Very High	0	0
B	High	1	0
C	Medium	2	0
D	Low	2	5
Calculated Overall Threat Impact:		Very High	Medium

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
1	Residential & commercial development		Negligible	Negligible (<1%)	Negligible(<1%)	High (Continuing)	
1.1	Housing & urban areas						
1.2	Commercial & industrial areas						
1.3	Tourism & recreation areas		Negligible	Negligible(<1%)	Negligible (<1%)	High (Continuing)	Some colony areas are used for camping; land-based fishing lodges may alienate habitat.
2	Agriculture & aquaculture		Negligible	Negligible (<1%)	Negligible (<1%)	High (Continuing)	
2.1	Annual & perennial non-timber crops						
2.2	Wood & pulp plantations						
2.3	Livestock farming & ranching						
2.4	Marine & freshwater aquaculture		Negligible	Negligible (<1%)	Negligible (<1%)	High (Continuing)	Footprints and side effects of facilities have some, but limited, overlap with juvenile Cassin's Auklet range.
3	Energy production & mining		Unknown	Restricted - Small(1-30%)	Unknown	Moderate (Possibly in the short term, < 10 yrs)	
3.1	Oil & gas drilling		Not Calculated (outside assessment timeframe)	Unknown	Unknown	Low (Possibly in the long term, >10 yrs)	Offshore oil and gas activities would be potentially significant.
3.2	Mining & quarrying						Contamination from mine tailings is covered in Section 9.2

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
3.3	Renewable energy		Unknown	Restricted - Small (1-30%)	Unknown	Moderate (Possibly in the short term, < 10 yrs)	Impacts of offshore wind turbines are unknown, but are more likely to be related to disturbance than to direct mortality; direct mortality effects are expected to be low. Wind farm developments would almost certainly affect no more than 30% of the population: scope and severity will depend on where turbines are placed.
4	Transportation & service corridors	D	Low	Large - Restricted (11-70%)	Slight (1-10%)	High (Continuing)	
4.1	Roads & railroads						
4.2	Utility & service lines						
4.3	Shipping lanes	D	Low	Large - Restricted (11-70%)	Slight (1-10%)	High (Continuing)	This section covers unquantified threats of disturbance and collisions with ships, including collisions due to the birds' attraction to ship lights at night. Effects of disturbance are expected to be greater than direct mortality from collisions. This ongoing threat is not expected to exceed a 1% threshold for severity at present levels of boat traffic. However, shipping is projected to increase in coastal BC and impacts on the Cassin's Auklet population will depend on the where increases occur. Contamination from chronic oiling, catastrophic oil spills and industrial pollution is covered in Sections 9.2 and 9.5. Cumulatively, disturbance, collisions and contamination from oil and other pollutants could have a large effect on Cassin's Auklet populations.
4.4	Flight paths						
5	Biological resource use		Negligible	Large - Restricted (11-70%)	Negligible (<1%)	High (Continuing)	
5.1	Hunting & collecting terrestrial animals		Unknown	Unknown	Unknown	Unknown	The frequency of First Nations' collections of birds and eggs is unknown, but is likely not a concern at the population level.
5.2	Gathering terrestrial plants						Gathering of plants by First Nations may impact the birds' burrows; this threat was not scored here because it is considered lower than 'neglible'.
5.3	Logging & wood harvesting		Negligible	Negligible (<1%)	Negligible (<1%)	Moderate (Possibly in the short term, < 10 yrs)	Almost all colony islands in BC are protected from logging; shoreline log salvage during the nesting season remains a threat. With climate change, currently unprotected islands could be colonized (this could happen within 20 years).

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
5.4	Fishing & harvesting aquatic resources		Negligible	Large - Restricted (11-70%)	Negligible (<1%)	High (Continuing)	Net entanglement rates are likely low (based on minimal information); spatial overlap with the euphausiid fishery is minimal.
6	Human intrusions & disturbance		Negligible	Negligible (<1%)	Negligible (<1%)	High (Continuing)	
6.1	Recreational activities		Negligible	Negligible (<1%)	Negligible (<1%)	High (Continuing)	There is a potential for disturbance at colonies.
6.2	War, civil unrest & military exercises						
6.3	Work & other activities		Negligible	Negligible (<1%)	Negligible (<1%)	High (Continuing)	Scientific research and associated activities involving the presence of people on colony islands affects the population. Research projects have resulted in mortality of breeding birds and reduced reproductive success; the potential for corrupting a small number of burrows exists.
7	Natural system modifications	D	Low	Pervasive (71-100%)	Slight (1-10%)	High (Continuing)	
7.1	Fire & fire suppression						
7.2	Dams & water management/use						
7.3	Other ecosystem modifications	D	Low	Pervasive (71-100%)	Slight (1-10%)	High (Continuing)	This section includes modifications to vegetation and soils due to activities of non-native deer, rabbits and plants though the severity is unknown. Changes to native vegetation (e.g. salmonberries) and impacts of droughts are also considered here. Climate change is covered in Section 11.
8	Invasive & other problematic species & genes	CD	Medium - Low	Restricted - Small (1-30%)	Extreme – Serious (31-100%)	High (Continuing)	
8.1	Invasive non-native/alien species	CD	Medium - Low	Restricted - Small (1-30%)	Extreme - Serious(31-100%)	High (Continuing)	Rats, raccoons and mink predation are a threat; the impacts of deer and rabbits are unknown.
8.2	Problematic native species						Otter, eagle, Peregrine Falcon and gull predation impact populations, but these are not considered "problematic" species.
8.3	Introduced genetic material						
9	Pollution	BD	High - Low	Large - Restricted (11-70%)	Serious - Slight (1-70%)	High (Continuing)	
9.1	Household sewage & urban waste water						

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
9.2	Industrial & military effluents	BD	High - Low	Large - Restricted (11-70%)	Serious - Slight (1-70%)	High (Continuing)	Catastrophic and chronic oil spills are included here (direct shipping effects are covered in Section 4.3). The birds are vulnerable if they encounter oil. The degree of threat will depend on the timing and location of a catastrophic event: significant impacts at the population level may occur. Actual impacts are greatly underestimated as many smaller birds sink and are never found. Increased shipping traffic in BC waters will greatly increase this threat. Note that timing is considered 'continuing' here based on the threat of chronic, rather than catastrophic, oiling.
9.3	Agricultural & forestry effluents						
9.4	Garbage & solid waste		Negligible	Negligible (<1%)	Negligible (<1%)	High (Continuing)	Based on information on other species of diving seabirds, it is possible that Cassin's Auklets are affected by plastics pollution in the marine environment. Population-level effects of plastics are unknown, but are not expected for Cassin's Auklet.
9.5	Air-borne pollutants		Unknown	Unknown	Unknown	High (Continuing)	Effects of levels of contamination reported in North American waters are unknown.
9.6	Excess energy						Noise and light from shipping, including fishing operations, are covered in Section 4.3.
10	Geological events		Unknown	Unknown	Unknown	Unknown	
10.1	Volcanoes						
10.2	Earthquakes/tsunamis		Unknown	Unknown	Unknown	Unknown	A tsunami could have a large effect, but the likelihood of such an event within the range of Cassin's Auklet is unknown.
10.3	Avalanches/landslides						
11	Climate change & severe weather	CD	Medium - Low	Pervasive (71-100%)	Moderate - Slight (1-30%)	High (Continuing)	
11.1	Habitat shifting & alteration	CD	Medium - Low	Pervasive (71-100%)	Moderate - Slight (1-30%)	High (Continuing)	Impacts to both the marine and terrestrial habitats are covered in this section; marine ecosystem alterations and vegetation changes at some colonies were considered.
11.2	Droughts						Vegetation changes due to droughts are covered in Section 7.3
11.3	Temperature extremes						

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
11.4	Storms & flooding		Not Calculated (outside assessment timeframe)	Unknown	Unknown	Low (Possibly in the long term, >10 yrs)	Storms and flooding have the potential to impact foraging and burrow integrity.